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Inventory of Combustion-Related Emissions from Stationary Sources (Second Update)

Aerospace Corp, El Segundo, Calif

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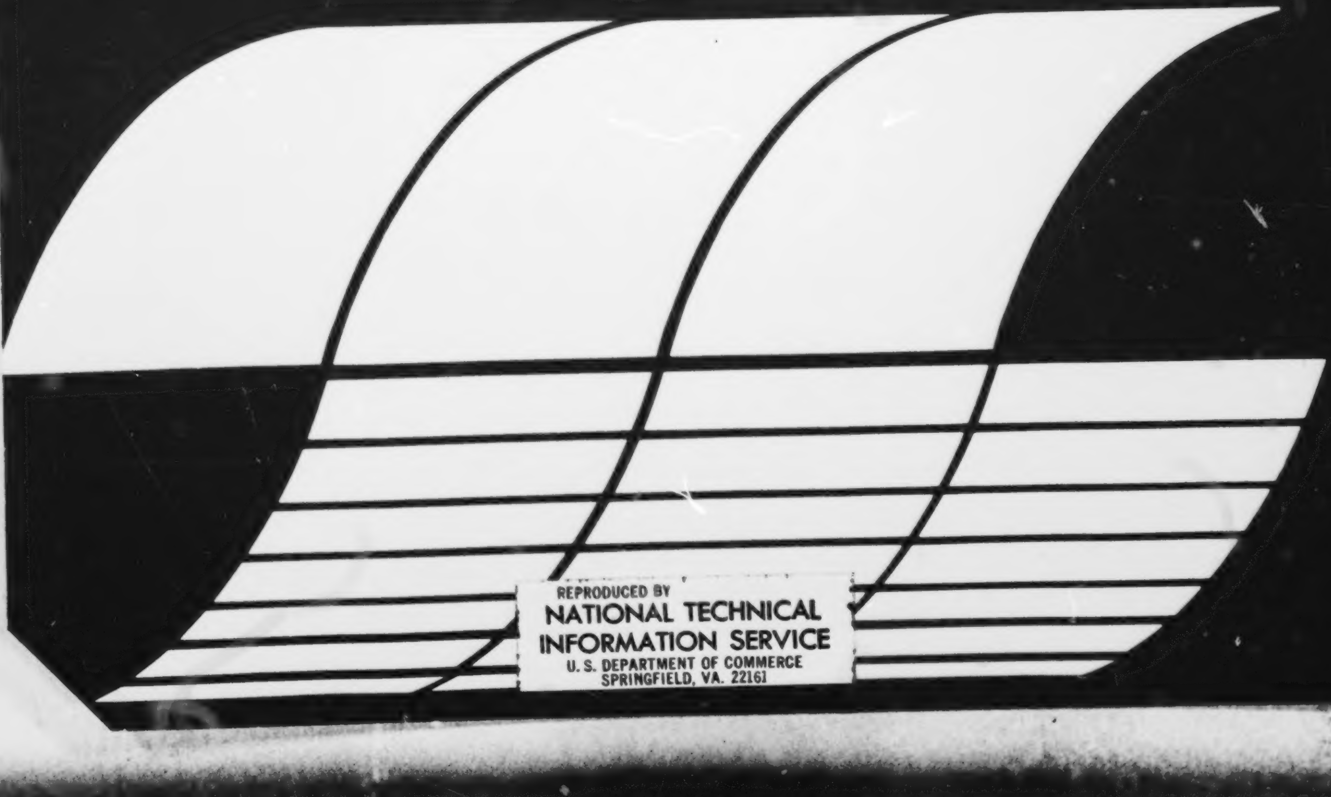
Interagency Energy/Environment R&D Program Report



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16. ABSTRACT The report describes the full period of a study covering the combustion-related emissions phase of a 3-year program on the analysis of NOx control in stationary sources. The study was aimed at helping to establish priorities for detailed studies of techniques for controlling combustion-related emissions from stationary sources. The inventory includes emissions of NOx, HC, CO, and particulates from stationary sources, not only primarily involving combustion but also where combustion plays a secondary role. During each of the 3 years of the study, emissions were inventoried for selected industries or processes: (1st year) boilers, stationary IC engines, chemical manufacturing, and petroleum refining; (2nd year) primary metals and HC evaporation; (3rd year) secondary metals and mineral and wood products. The report identifies 91-98% of the stationary sources of the four air pollutants. Charge rates, emissions, and uncertainties in all data are projected into the future and, in this report, are shown for the years 1977 and 1982.

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17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS		b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group	
Air Pollution	Dust	Air Pollution Control	13B	11G
Combustion	Boilers	Stationary Sources	21B	13A
Emission	Internal Combustion Engines	Particulates	14B	
Inventories		Emissions Inventory		21G
Nitrogen Oxides	Chemical Industry	Mineral Products	07B	07A
Hydrocarbons	Metal Industry	Primary Metals	07C	11F
Carbon Monoxide	Wood Products	Secondary Metals		11L

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by

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Grant No. R803283
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i.a

ABSTRACT

This report describes a three-year study performed by The Aerospace Corporation to satisfy the Emissions Inventory phase of a federal grant entitled "Analysis of NO_x Control in Stationary Sources." The grant defines a three-year program covering the period 15 July 1974 to 30 April 1978. The purpose of this phase of the program is to assist the Environmental Protection Agency in establishing priorities for detailed studies of techniques for the control of combustion-related stationary source atmospheric emissions of (1) oxides of nitrogen, (2) unburned hydrocarbons, (3) carbon monoxide, and (4) particulate matter. The emissions inventoried are from recognized major stationary combustion sources as well as from stationary source categories in which combustion plays a secondary role. During the first year of this study, the emissions inventory was determined for boilers, internal combustion engines, chemical manufacturing, and petroleum refining. In the second year, the inventory was obtained for point-source evaporation and primary metals industries. The third year of the study added mineral products, secondary metals, and wood products to the inventory and updated the data base for the boiler category. This report now identifies more than 90 percent of all emissions of the four air pollutants from stationary point sources.

This report is submitted by The Aerospace Corporation under sponsorship of the Environmental Protection Agency in partial fulfillment of Grant Number R803283. The remainder of the grant involves an analysis of the control of oxides of nitrogen in stationary systems. The first two-years of the emissions inventory study have been reported by Aerospace in Inventory of Combustion-Related Emissions from Stationary Sources (First Update), EPA-600/2-77-066a, dated March 1977.

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SECTION I

EXECUTIVE SUMMARY

1.1 INTRODUCTION

1.1.1 Background

A cost-effective approach to nationwide reduction of air pollution requires an accurate assessment of the air pollutants being discharged into the atmosphere by combustion-related processes and other related activities. Since there is a long lead time between the recognition of a large source of air pollution and the implementation of control methods, it is further required that the magnitude of these emissions be estimated for an appropriate time in the future.

Studies of specific industries have been conducted. Because the sources of air pollution are numerous and geographically scattered, few studies have involved the gathering of significant samples of measured emission data. Most tend to review, analyze, summarize, and project the same data.

The National Emissions Data System (NEDS) of the U. S. Environmental Protection Agency (EPA) has generated a large volume of detailed, measured emission data, covering a wide range of industries. Most of these data were gathered in the 1970 through 1972 time period. Efforts to update the NEDS data base are continuing. However, as of 1977, the NEDS data were incomplete, contained some errors, and represented data from an average time period of about 1971. The NEDS contains no means for projecting the data beyond the acquisition period. Despite these drawbacks, the NEDS has the largest, most comprehensive, and detailed sample of original emission data available.

The other studies containing original data surveys serve as a check on the completeness of the NEDS data and provide the rationale for projection of the data into the future.

1.1.2 Scope

The purpose of this study, which was part of a three-year program, is to assist the EPA in establishing priorities for combustion-related detailed air pollution control studies. The atmospheric pollutants of interest are oxides of nitrogen (NO_x), unburned hydrocarbons (HC), particulate matter (PART), and carbon monoxide (CO). The study utilized the NEDS original emission data base, as well as original data obtained from other published studies and contacts with manufacturers' associations, to generate a detailed inventory of emissions, with projections into the future.

The nationwide emissions inventory compiled by this study is limited to atmospheric point source emissions. Point sources are defined, for this study, as stationary sources contributing more than 100 tons per year of pollutant. Area sources (i.e., stationary sources of pollution exclusive of point sources) are considered only in cases where the area source is likely to be large compared to the point source.

The industries from which the emissions of interest emanate are referred to as process or source categories and are classified under the NEDS Source Classification Code (SCC). A detailed breakdown of these source categories is further defined by the Modified SCC (MSCC) developed by The Aerospace Corporation for this study. The emissions inventoried during the first year of the study, reported here, are from the following major source categories: external combustion in boilers, internal combustion, chemical manufacturing, and petroleum refineries. Evaporation and primary metals emissions were studied in the second year of the program; emissions from mineral product, secondary metal, and wood product industries were included in the third year.

Uncertainty values are given for the current emission estimates and for emission projections to the early 1980s. The variables determining these values are process usage rates, emission factors, control applications, and time derivatives or trends. Statistical engineering estimates, current and potential legislative controls, and several independent sources of data were considered in calculating the uncertainty of each of the emissions inventoried.

1.1.3 Objectives

The objectives of this study are as follows:

a. Establish current and future five-year estimates of significant nationwide atmospheric stationary point source emissions of particulates, NO_x, HC, and CO, particularly from industries involving combustion.

b. Determine the uncertainty of current and future emission rates.

1.1.4 Approach

The objectives of the study were accomplished by the performance of the following tasks:

a. Establish a list of processes which yield a significant quantity of atmospheric emissions. The selection of processes and subprocesses is described in Sections 1.4.1 and 1.4.2.

b. Determine a data base (starting point) and slopes for time-dependent variables from which current and future emissions can be calculated. Accomplishment of this task for each process is described in Sections II through X.

c. Establish and code equations, for computer usage, which allow emissions and their uncertainties to be estimated for the year of interest. Section 1.5 describes these equations.

d. Calculate and publish emissions for the current year and the fifth year hence. The detailed results of these calculations are listed for each process in Sections II through X. The summarized results are published in Section 1.3.

1.1.5. Organization of Report

Data tables presented throughout this report are for the years 1977 and 1982. The Executive Summary section presents (1) an overview of the study and a concise review of the significant results; (2) an inventory summary of the 1977 and 1982 emissions, charge rates, and uncertainties for the broadest categories of the process studies; and

(3) a description of the data acquisition techniques and the methods used to perform the computational analyses. Each of the major processes studied in the emissions inventory is presented separately in Sections II through X. For the convenience of selective users, these sections are independently oriented.

The overall study was a three-year effort. Each year a selected industry, process, or group of sources was studied. Also, during the third year, the inventory of the external combustion boiler category was updated. The basic report was revised annually during the course of the study, with subsequent inventories and the update of the boiler category incorporated.

Metric equivalents for English units used in this report are listed in the conversion table in Appendix A. A glossary of terms is provided in Appendix B.

1.2 STUDY SUMMARY

The percentage distribution of the emissions of the four air pollutants among the stationary point source categories inventoried is shown in Table 1-1. Table 1-2 shows the quantities of the emissions from each of these categories and these same data are shown graphically in Figure 1-1.

Table 1-1 shows that this inventory covered more than 90 percent of all of the stationary point sources of the four air pollutants. This study was restricted to stationary point sources. In general, a point source is defined as a single geographical location from which more than 100 tons of an air pollutant are emitted annually. Sources too small to qualify as point sources are summed over certain geographical areas and are cited as area sources. In that regard, this inventory covered more than 80 percent of all stationary sources (point plus area) of all of the four air pollutants except hydrocarbons (HC); only 62 percent of all of the stationary sources of HC emissions (point plus area) were covered. The large area source of HC emissions is primarily the unloading of tank trucks and the filling of motor vehicles at retail gasoline service stations (vapor displacement sources).

Table 1-1. 1977 DISTRIBUTION OF POINT SOURCE EMISSIONS

Source Category	Percent of Total Point Source Emissions[a]			
	NO_x	HC	CO	PART
Steam Boilers	84	3	2	37
Internal Combustion Engines	6	6	Neg	Neg
Chemical Manufacturing	Neg	16	9	Neg
Petroleum Refineries	5	6	47	2
Evaporation	Neg	57	Neg	Neg
Primary Metals	Neg	3	33	8
Secondary Metals	Neg	Neg	3	1
Mineral Products	3	Neg	Neg	43
Wood Products	Neg	Neg	2	2
Total Inventoried	98	91	96	93
Other Point Sources[b]	2	9	4	7
Total Stationary Point Sources	100	100	100	100

[a] "Neg" is defined as less than 0.5%.

[b] Data from Nationwide Emission Summary, National Emissions Data Systems, U. S. Environmental Protection Agency, Research Triangle Park, North Carolina (November 15, 1976).

Table 1-2. 1977 AND 1982 STATIONARY POINT SOURCE EMISSIONS

Source Category		Emissions, million tons/year[a]			
		NO_x	HC	CO	PART
Steam Boilers	1977	8.01	0.20	0.51	6.59
	1982	6.47	0.25	0.61	6.35
Internal Combustion Engines	1977	0.59	0.38	Neg	Neg
	1982	0.55	0.45	Neg	Neg
Chemical Manufacturing	1977	Neg	1.10	2.68	Neg
	1982	Neg	1.14	2.82	Neg
Petroleum Refineries	1977	0.49	0.43	15.07	0.28
	1982	0.31	0.47	8.97	0.21
Evaporation	1977	Neg	3.84	Neg	Neg
	1982	Neg	2.26	Neg	Neg
Primary Metals	1977	0.01	0.20	10.41	1.38
	1982	0.01	0.20	5.72	0.65
Secondary Metals	1977	0.03	0.02	0.82	0.16
	1982	0.03	0.02	0.38	0.07
Mineral Products	1977	0.29	0.01	0.06	7.71
	1982	0.31	0.01	0.05	6.40
Wood Products	1977	Neg	0.03	0.66	0.33
	1982	Neg	0.02	0.40	0.34

[a] "Neg" is defined as less than 1% of the emissions for that category.

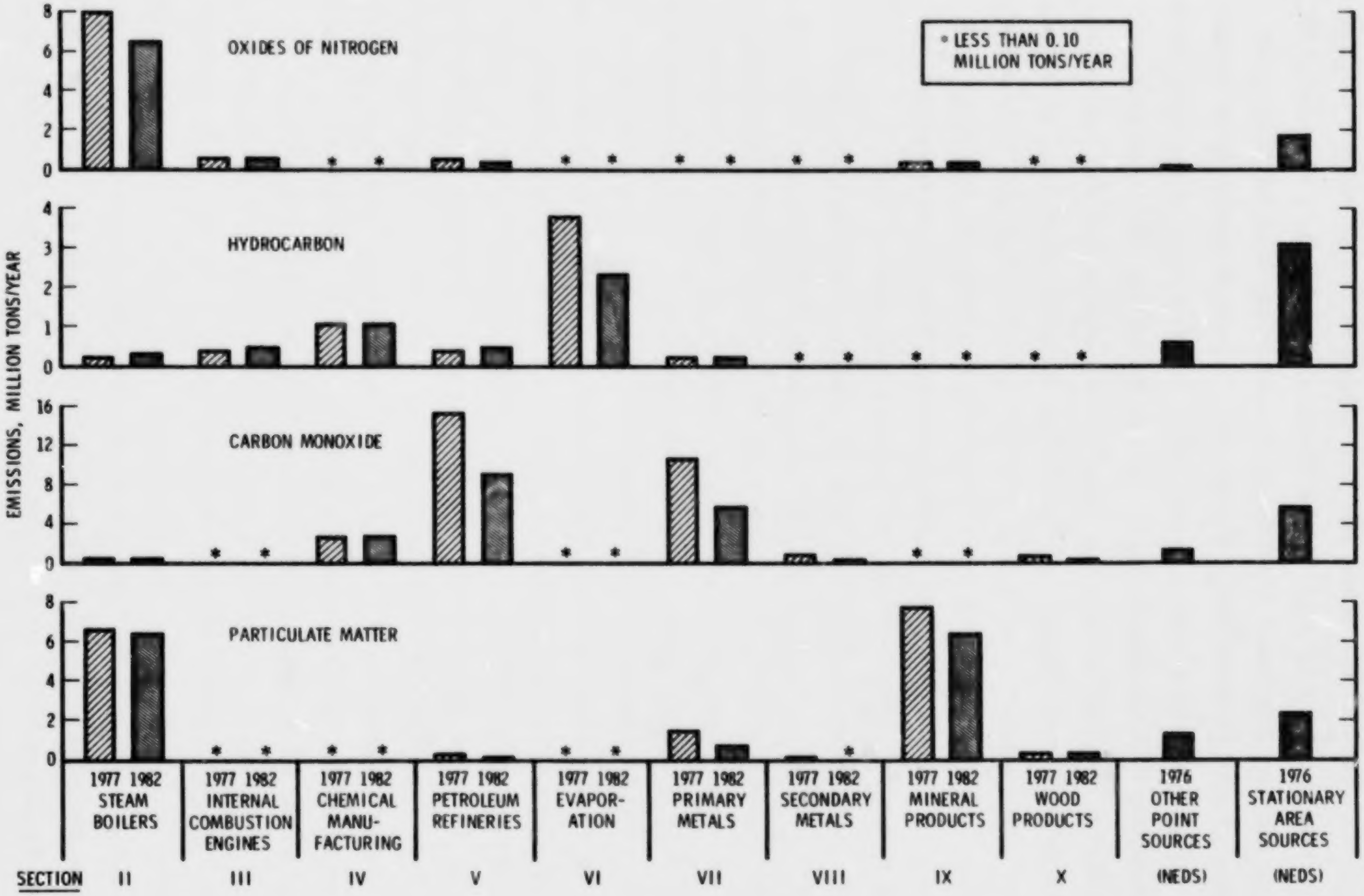

Figure 1-1. 1977 and 1982 emissions from stationary sources

Table 1-1 shows that the category called steam (utility and industrial) boilers is clearly the dominant stationary source of NO_x emissions and the dominant stationary combustion-related source of particulate (PART) emissions. Of the NO_x emitted from these steam boilers, 85 percent is emitted from utility boilers and 74 percent from the combustion of bituminous coal. Of all the particulate emissions from steam boilers, 76 and 94 percent result from utility boilers and bituminous coal combustion, respectively. The largest single source of particulate emissions, as shown in Table 1-1, is the category called Mineral Products. These particulates, however, are largely from stone processing and cement and asphaltic concrete plants (noncombustion sources) and the particulate species involved are not usually considered toxic.

Although the NO_x and CO emissions shown in Table 1-1 for the point source category of Internal Combustion Engines are both small, there may be very large amounts of both air pollutants being emitted by very large numbers of small engines (grouped in an area source). For example, well over one million gasoline-powered internal combustion engines were shipped from manufacturers every year for the last 10 years, for uses ranging from small power tools to compressors, pumps and electrical power installations. Little data are available, however, on the actual applications of these small engines, their average useful life, or their usage rates or duty cycles. Thus the magnitude of this possible stationary area source of NO_x and CO is highly uncertain. Under a worst case (but possible) set of assumptions, this area source could represent the largest single stationary source of both NO_x and CO. Efforts to accurately inventory this area source appear warranted.

Table 1-1 shows that the major stationary point source of CO is the category called Petroleum Refineries. These CO emissions result almost entirely from processes involved in the catalytic cracking of petroleum during the refining process. The related combustion process is the periodic regeneration of the catalyst by burning off the coke (with air) which becomes deposited on the catalyst. There is, however, a great deal of uncertainty in the estimates of CO emissions from this source. Table 1-2 shows that CO emissions from petroleum refineries in 1977 were estimated at 15.1 million tons, but Table 1-3 shows that this estimate is uncertain within 6.2 million tons (41 percent). These estimates of CO emissions from this process are higher than those of the National Environmental Data Systems (NEDS) by more than a factor of five. The large uncertainties result primarily from the wide ranges of emission factors found in various data sources. These emission factor uncertainties, in turn, are thought to result from a lack of data on, and even the possible day-to-day variations in, the type of after-treatment and/or use of the CO-rich gases from the catalyst regeneration process in the various refineries. Waste heat boilers, if in use, can be very effective in reducing these CO emissions. There was not sufficient time in this study to resolve these uncertainties.

Table 1-1 shows that the majority of the HC emissions from stationary point sources result from evaporation of various hydrocarbon fluids, primarily during various surface coating and petroleum storage, transportation and marketing processes (noncombustion processes). This category is an even larger source of HC emissions when the area source associated with retail gasoline service station evaporation is also considered. The relatively large HC emissions shown in Table 1-1 in the Chemical Manufacturing category are largely due to combustion processes involved in the production of carbon black and ammonia.

Figure 1-1 graphically shows the preponderance of the emissions from the source categories as discussed in this section. Table 1-2 shows the related emission levels, in millions of tons per year. In addition, Figure 1-1 shows the projected trends in the emissions of the pollutants from each source category, to a time five years in the future. In general, all emissions from all source categories show decreasing trends with time. The total emissions of each of the four pollutants from all of the stationary point sources inventoried all show decreasing trends ranging from 20 to 32 percent over the five-year

Table 1-3. UNCERTAINTIES IN 1977 POINT SOURCE EMISSION RATES

Source Category	Uncertainty, million tons/year[a]			
	NO_x	HC	CO	PART
Steam Boilers	+0.52	+0.11	+0.09	+0.60
	-0.52	-0.03	-0.06	-0.60
Internal Combustion Engines	+0.40	+0.21	Neg	Neg
	-0.15	-0.07	Neg	Neg
Chemical Manufacturing	Neg	+0.12	+0.49	Neg
	Neg	-0.12	-0.44	Neg
Petroleum Industry	+0.03	+0.04	+6.22	+0.01
	-0.03	-0.04	-6.22	-0.01
Evaporation	Neg	+0.53	Neg	Neg
	Neg	-0.44	Neg	Neg
Primary Metals	Neg	+0.02	+1.58	+0.35
	Neg	-0.06	-1.58	-0.26
Secondary Metals	Neg	Neg	+0.13	+0.05
	Neg	Neg	-0.13	-0.06
Mineral Products	+0.04	Neg	Neg	+1.01
	-0.02	Neg	Neg	-1.05
Wood Products	Neg	Neg	+0.40	+0.17
	Neg	Neg	-0.40	-0.20

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[a] "Neg" is defined when the nominal emissions are less than 1% of the total stationary point source emissions.

period (best estimates). Even worst case estimates, within the ranges of uncertainties, show little or no increases in total emissions of any of the four air pollutants over that time period. The decreasing trends are primarily the result of increasingly widespread application of existing or planned near-term new source performance standards.

1.3 INVENTORY SUMMARY

The categories studied are classified and summarized under the processes contributing the stationary source emissions of interest. In Table 1-4, the major process categories investigated are listed and defined according to the Modified NEDS Source Classification Code (MSCC) and charge rate units. The 1977 and 1982 emissions are summarized by major process category in Tables 1-5-a and 1-6-a, respectively. The respective uncertainties for these emissions are given in Tables 1-5-b and 1-6-b.

In these tables, three levels of summarization are defined by the nine-digit MSCC number. The first, most general, summary level is indicated by the first digit of the MSCC. The emissions listed in the first-level summary categories are the sum of those in the second-level summary, and those in the second level are the sum of those in the third level. Second-level categories are indicated by the second and third digits in the MSCC, and the third-level summary categories by the numbers in the fourth, fifth, and sixth digits.

No charge rates are listed for the first level and only a few for the second-level summary categories because these categories represent different types of processes with different units of measure. For example, the second-level summary category 101000000 represents all external combustion for boilers used in electric generation including those burning coal in tons per year, oil in thousands of gallons per year, and natural gas in millions of cubic feet per year. In some cases, third-level summaries involve a single process type with the same units, e.g., 1010020000, bituminous coal in tons per year. In such cases, the appropriate MSCC unit of measure is shown in Table 1-4, and a charge rate for this unit is listed in Tables 1-5 and 1-6.

(Continued on page 1-77)

Table 1-4. DEFINITION OF SUMMARY CATEGORIES

MSCC	Source Category	Charge Rate Unit[a]
100000000	External Combustion (Boiler)	
101000000	Electric Generation	
101002000	Bituminous coal	Tons burned/yr
101004000	Residual oil	1000 gal /yr
101005000	Distillate oil	1000 gal/yr
101006000	Natural gas	Million cu ft/yr
101007000	Process gas	Million cu ft/yr
102000000	Industrial	
102002000	Bituminous coal	Tons burned/yr
102004000	Residual oil	1000 gal/yr
102005000	Distillate oil	1000 gal/yr
102006000	Natural gas	Million cu ft/yr
102007000	Process gas	Million cu ft/yr
200000000	Internal Combustion	
201000000	Electric Generation	
201001000	Distillate oil	1000 gal/yr
201002000	Natural gas	Million cu ft/yr
201003000	Diesel	1000 gal/yr
201999000	Miscellaneous fuel	N. A.
202000000	Industrial IC Engines	
202001000	Distillate oil turbine	1000 gal/yr
202002000	Distillate oil reciprocating	1000 gal/yr
202003000	Natural gas turbine	Million cu ft/yr
202004000	Natural gas reciprocating	Million cu ft/yr
202999000	Miscellaneous fuels[b]	Million cu ft/yr

Table 1-4. DEFINITION OF SUMMARY CATEGORIES (Continued)

MSCC	Source Category	Charge Rate Unit[a]
300000000	Industrial Processes	
301000000	Chemical Manufacturing	
301002000	Ammonia production with methanator	Tons/yr
301003000	Ammonia production with CO absorber	Tons/yr
301005000	Carbon black production	Tons/yr
301999000	Miscellaneous chemical manufacturing	Tons/yr
303000000	Primary Metals	N. A.
303001000	Aluminum reduction	Aluminum, tons/yr
303002000	Aluminum ore calcined	Tons/yr
303003000	Coke metallurgical	Coal, tons/yr
303004000	Coke beehive	Coal, tons/yr
303005000	Copper smelters	N. A.
303006000	Ferroalloy production (open furnace)	Tons/yr
303007000	Ferroalloy production (closed furnace)	
303008000	Iron production	N. A.
303009000	Steel production	Tons/yr
303010000	Lead smelters	N. A.
303011000	Molybdenum	N. A.
303012000	Titanium	N. A.
303030000	Zinc smelting	Tons/yr
303999000	Miscellaneous metallurgical processes	Tons/yr
304000000	Secondary Metals	
304001000	Aluminum operations	Tons/yr
304002000	Brass/bronze melt	Tons/yr

(continued)

Table 1-4. DEFINITION OF SUMMARY CATEGORIES (Continued)

MSCC	Source Category	Charge Rate Unit[a]
304003000	Gray iron	Tons/yr
304004000	Secondary lead smelting	Tons/yr
304006000	Secondary magnesium	Tons/yr
304007000	Steel foundry	Tons/yr
304008000	Secondary zinc	Tons/yr
304009000	Malleable iron	Tons/yr
304010000	Nickel	Tons/yr
304020000	Furnace electrodes	Tons/yr
304050000	Misc. casting & fabrication	Tons/yr
304999000	Misc. secondary metal activity	Tons/yr
305000000	Mineral Products	
305002000	Asphaltic concrete	Tons/yr
305003000	Brick manufacturing	Tons/yr
305005000	Castable refractory	Tons/yr
305006000	Cement mfg., dry	N. A.
305007000	Cement mfg., wet	N. A.
305008000	Ceramic/clay mfg.	Tons/yr
305009000	Clay/fly ash sinter	Tons/yr
305010000	Coal cleaning	Tons/yr
305014000	Glass mfg.	Tons/yr
305015000	Gypsum mfg.	Tons/yr
305016000	Lime mfg.	Tons/yr
305018000	Perlite mfg.	Tons/yr
305020000	Stone quarry process	Tons/yr
305022000	Potash production	Tons/yr
305024000	Magnesium carbinate	Tons/yr

(continued)

Table 1-4. DEFINITION OF SUMMARY CATEGORIES (Continued)

MSCC	Source Category	Charge Rate Unit[a]
305025000	Sand & gravel processing	Tons/yr
305999000	Miscellaneous mineral products	N. A
306000000	Petroleum Industry	
306001000	Process heater	N. A
306002000	Fluid catalytic crackers	1000 bbl/yr
306003000	Moving bed catalytic crackers	1000 bbl/yr
306008000	Miscellaneous leakage	Capacity, 1000 bbl/yr
306012000	Fluid coking	Feed, 1000 bbl/yr
307000000	Wood Products	
307001000	Sulfate pulping	Tons/yr, air dried
307002000	Sulfite pulping	Tons/yr, air dried
307004000	Pulpboard mfg.	Tons/yr
307006000	Tall oil/rosin	Tons/yr
307007000	Plywood/particle board	Tons/yr
307008000	Sawmill operations	Tons/yr
307020000	Furniture manufacturing	Tons/yr
307999000	Miscellaneous wood products	Tons/yr
400000000	Point Source Evaporation	N. A
401000000	Cleaning Solvents	N. A.
401001000	Dry cleaning	Clothes, tons/yr
401002000	Degreasing	Solvent, tons/yr
401999000	Miscellaneous solvent use	Solvent, tons/yr

Table 1-4. DEFINITION OF SUMMARY CATEGORIES (Continued)

MSCC	Source Category	Charge Rate Unit[a]
402000000	Surface Coating	Coating, tons/yr
402001000	Paint	Coating, tons/yr
402002000	Paper coatings	Coating, tons/yr
402003000	Varnish and shellac	Coating, tons/yr
402004000	Lacquer	Coating, tons/yr
402005000	Enamel	Coating, tons/yr
402006000	Primer	Coating, tons/yr
402007000	Fabric coatings	Coating, tons/yr
402008000	Oven coatings	Coating, tons/yr
402999000	Miscellaneous coatings	Coating, tons/yr
403000000	Petroleum Storage	N. A.
403001000	Fixed roof	N. A.
403002000	Floating roof	N. A.
403003000	Variable vapor space	1000 gal/yr
403999000	Miscellaneous storage	1000 gal/yr
406000000	Petroleum Marketing & Transportation	1000 gal/yr
406001000	Rail and truck transportation	1000 gal/yr
406002000	Marine vessel transportation	1000 gal/yr

[a] N. A. (not applicable) is listed under "Charge Rate Unit" where the MSCC number is made up of two or more MSCCs whose charge rates are different.

[b] Although this category is made up of two MSCC's whose units are different, only one (202999970) was studied.

Table 1-5-a. SUMMARY OF 1977 EMISSIONS AND CHARGE RATES

```
                                SUMMARY OF MAJOR CATEGORIES

                          EXTERNAL COMBUSTION, BOILER CATEGORY                          PAGE   1
ANNUAL CHARGE RATES AND EMISSIONS PROJECTED TO 1977      RUN DATE= NOV 16,1977
 MODIFIED         TACRP                        EMISSIONS (MILLIONS OF TONS / YEAR)
   SCC         (SCC UNITS)           NOX            HC              CO              PART
100000000
                                     8.006          .201            .506            6.577
101000000
                                     6.128          .106            .285            4.497
101002000        438640000.          5.091
101004000         24200000.           .631          .080            .226            4.381
101005000                0.          0.000          .024            .036             .097
101006000          2597200.           .415         0.000           0.000            0.000
101007000            90390.           .000          .001            .022             .019
                                                    NEG             NEG              NEG
102000000
                                     1.878          .095            .221            2.079
102002000        107910000.          1.043
102004000         18220000.           .328          .050            .123            1.774
102005000          6720000.           .121          .027            .042             .210
102006000          5011000.           .386          .010            .013             .050
102007000          1749300.           .000          .008            .043             .045
                                                    NEG             NEG              NEG
```

MSCC	Source Category	Charge Rate Unit
100000000	External Combustion (Boiler)	
101000000	Electric Generation	
101002000	Bituminous coal	Tons burned/yr
101004000	Residual oil	1000 gal/yr
101005000	Distillate oil	1000 gal/yr
101006000	Natural gas	Million cu ft/yr
101007000	Process gas	Million cu ft/yr
102000000	Industrial	
102002000	Bituminous coal	Tons burned/yr
102004000	Residual oil	1000 gal/yr
102005000	Distillate oil	1000 gal/yr
102006000	Natural gas	Million cu ft/yr
102007000	Process gas	Million cu ft/yr

Table 1-5-a. SUMMARY OF 1977 EMISSIONS AND CHARGE RATES (Continued)

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                              SUMMARY OF MAJOR CATEGORIES
                              INTERNAL COMBUSTION ENGINES                                  PAGE  1
ANNUAL CHARGE RATES AND EMISSIONS PROJECTED TO 1977       RUN DATE= NOV 16,1977
 MODIFIED          TACRF                       EMISSIONS (MILLIONS OF TONS / YEAR)
   SCC          (SCC UNITS)           NOX             HC              CO              PART
200000000
                                      .590            .376            .067            .017
201000000
                                      .248            .093            .017            .012
201001000          1163100.           .129            .002            .010            .003
201002000           319570.           .091            .001            .000            .000
201003000            78259.           .011            .001            .005            .002
201999000                             .018            .090            .002            .001
```

MSCC	Source Category	Charge Rate Unit[a]
200000000	Internal Combustion	
201000000	Electric Generation	
201001000	Distillate oil	1000 gal/yr
201002000	Natural gas	Million cu ft/yr
201003000	Diesel	1000 gal/yr
201999000	Miscellaneous fuel	N.A.

[a] N.A. (not applicable) is listed under "Charge Rate Unit" where the MSCC number is made up of two or more MSCCs whose charge rates are different.

Table 1-5-a. SUMMARY OF 1977 EMISSIONS AND CHARGE RATES (Continued)

```
                          SUMMARY OF MAJOR CATEGORIES
                          INTERNAL COMBUSTION ENGINES                          PAGE  2
ANNUAL CHARGE RATES AND EMISSIONS PROJECTED TO 1977     RUN DATE= NOV 16,1977
 MODIFIED        TACRF              EMISSIONS (MILLIONS OF TONS / YEAR)
   SCC       (SCC UNITS)       NOX          HC          CO          PART

202000000                      .341         .283        .050        .005

202001000        71473.        .004         .000        .002        .001
202002000       914110.        .327         .084        .041        .004
202003000         3933.        .000         .000        .003        .000
202004000        29971.        .005         .000        .002        .000
202999000        27466.        .004         .198        .001        .000
```

MSCC	Source Category	Charge Rate Unit
202000000	Industrial IC Engines	
202001000	Distillate oil turbine	1000 gal/yr
202002000	Distillate oil reciprocating	1000 gal/yr
202003000	Natural gas turbine	Million cu ft/yr
202004000	Natural gas reciprocating	Million cu ft/yr
202999000	Miscellaneous fuels[a]	Million cu ft/yr

[a] Although this category is made up of two MSCCs whose units are different, only one (202999970) was studied.

Table 1-5-a. SUMMARY OF 1977 EMISSIONS AND CHARGE RATES (Continued)

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                              SUMMARY OF MAJOR CATEGORIES
                      INDUSTRIAL PROCESS, CHEMICAL MANUFACTURING                  PAGE   1
ANNUAL CHARGE RATES AND EMISSIONS PROJECTED TO 1977     RUN DATE= NOV 16,1977
 MODIFIED          TACRP                 EMISSIONS (MILLIONS OF TONS / YEAR)
   SCC          (SCC UNITS)         NOX          HC             CO            PART
301000000
                                    NEG        1.098          2.680            NEG

301002000          6496800.         NEG         .223           .003            NEG
301003000          2598800.         NEG         .033           .049            NEG
301005000          6119400.         NEG         .324          2.292            NEG
301999000        151180000.         NEG         .518           .336            NEG
```

MSCC	Source Category	Charge Rate Unit
300000000	Industrial Processes	
301000000	Chemical Manufacturing	
301002000	Ammonia production with methanator	Tons/yr
301003000	Ammonia production with CO absorber	Tons/yr
301005000	Carbon black production	Tons/yr
301999000	Miscellaneous chemical manufacturing	Tons/yr

Table 1-5-a. SUMMARY OF 1977 EMISSIONS AND CHARGE RATES (Continued)

```
                              SUMMARY OF MAJOR CATEGORIES
                          INDUSTRIAL PROCESS, PRIMARY METALS                        PAGE  1
ANNUAL CHARGE RATES AND EMISSIONS PROJECTED TO 1977     RUN DATE= NOV 16,1977
 MODIFIED        TACRP                  EMISSIONS (MILLIONS OF TONS / YEAR)
   SCC        (SCC UNITS)          NOX           HC            CO            PART
303000000
                                   .013          .198          10.413        1.382

303001000       22338000.          NEG           NEG           NEG           .103
303002000        9046000.          NEG           NEG           NEG           .037
303003000      458400000.         .002          .184          .056          .078
303004000        1390000.          NEG          .006          .001          .122
303005000                          NEG           NEG           NEG           .340
303006000        4292500.          NEG           NEG           NEG           .132
303007000        2520000.          NEG           NEG           NEG           .002
```

MSCC	Source Category	Charge Rate Unit[a]
303000000	Primary Metals	N. A.
303001000	Aluminum reduction	Aluminum, tons/yr
303002000	Aluminum ore calcined	Tons/yr
303003000	Coke metallurgical	Coal, tons/yr
303004000	Coke beehive	Coal, tons/yr
303005000	Copper smelters	N. A.
303006000	Ferroalloy production (open furnace)	Tons/yr
303007000	Ferroalloy production (closed furnace)	

[a] N. A. (not applicable) is listed under "Charge Rate Unit" where the MSCC number is made up of two or more MSCCs whose charge rates are different.

Table 1-5-a. SUMMARY OF 1977 EMISSIONS AND CHARGE RATES (Continued)

```
                          SUMMARY OF MAJOR CATEGORIES
                       INDUSTRIAL PROCESS, PRIMARY METALS                          PAGE  2
ANNUAL CHARGE RATES AND EMISSIONS PROJECTED TO 1977      RUN DATE= NOV 16,1977
 MODIFIED         TACRF
   SCC         (SCC UNITS)               EMISSIONS (MILLIONS OF TONS / YEAR)
                                 NOX           HC            CO             PART
303008000                        NEG           NEG           6.518          .418
303009000      144630000.        .010          .006          3.835          .073
303010000        6780000.        .000          .000          NEG            .097
303011000                        NEG           NEG           NEG            .012
303012000          65000.        NEG           NEG           .002           NEG
303030000        1554000.        NEG           NEG           NEG            .005
303999000       32000000.        .001          .001          .002           .048
```

MSCC	Source Category	Charge Rate Unit[a]
303008000	Iron production	N. A.
303009000	Steel production	Tons/yr
303010000	Lead smelters	N. A.
303011000	Molybdenum	N. A.
303012000	Titanium	N. A.
303030000	Zinc smelting	Tons/yr
303999000	Miscellaneous metallurgical processes	Tons/yr

[a] N. A. (not applicable) is listed under "Charge Rate Unit" where the MSCC number is made up of two or more MSCCs whose charge rates are different.

Table 1-5-a. SUMMARY OF 1977 EMISSIONS AND CHARGE RATES (Continued)

```
                              SUMMARY OF MAJOR CATEGORIES

                     INDUSTRIAL PROCESS, SECONDARY METALS                     PAGE  1

ANNUAL CHARGE RATES AND EMISSIONS PROJECTED TO 1977     RUN DATE= NOV 16,1977

 MODIFIED          TACRF                   EMISSIONS (MILLIONS OF TONS / YEAR)
   SCC         (SCC UNITS)        NOX                HC                CO               PART

304000000                         .028              .016              .816              .159

304001000        3812400.         .001              .003               NEG              .006
304002000         451900.         .000              .000               NEG              .001
304003000       62197000.         .000              .002              .792              .034
304004000         664790.          NEG              .000               NEG              .000
304006000          18380.          NEG               NEG              .000               NEG
304007000      167470000.         .023              .004              .014              .104
304008000         570400.          NEG              .004               NEG              .002
304009000        1090000.          NEG               NEG              .008              .000
304010000          14700.          NEG               NEG              .001               NEG
304020000         275850.          NEG               NEG               NEG              .000
304050000        1448400.          NEG              .001               NEG              .001
304999000       11080000.         .002              .002               NEG              .010
```

MSCC	Source Category	Charge Rate Unit
304000000	Secondary Metals	
304001000	Aluminum operations	Tons/yr
304002000	Brass/bronze melt	Tons/yr
304003000	Gray iron	Tons/yr
304004000	Secondary lead smelting	Tons/yr
304006000	Secondary magnesium	Tons/yr
304007000	Steel foundry	Tons/yr
304008000	Secondary zinc	Tons/yr
304009000	Malleable iron	Tons/yr
304010000	Nickel	Tons/yr
304020000	Furnace electrodes	Tons/yr
304050000	Misc. casting & fabrication	Tons/yr
304999000	Misc. secondary metal activity	Tons/yr

Table 1-5-a. SUMMARY OF 1977 EMISSIONS AND CHARGE RATES (Continued)

SUMMARY OF MAJOR CATEGORIES

INDUSTRIAL PROCESS, MINERAL PRODUCTS

PAGE 1

ANNUAL CHARGE RATES AND EMISSIONS PROJECTED TO 1977 RUN DATE= NOV 16,1977

MODIFIED SCC	TACRF (SCC UNITS)	EMISSIONS (MILLIONS OF TONS / YEAR) NOX	HC	CO	PART
305000000		.294	.014	.055	7.712
305002000		.046	.001	.004	.634
305003000		NEG	NEG	NEG	.459
305005000		NEG	NEG	NEG	.003
305006000		.061	NEG	NEG	.601
305007000		.051	NEG	NEG	.548
305008000		.003	NEG	.001	.182
305009000		NEG	NEG	NEG	.029
305010000		.005	NEG	.001	.097
305014000		.019	NEG	NEG	.013
305015000		.002	NEG	NEG	.081
305016000		.003	.000	.002	.388
305018000		NEG	NEG	NEG	.002
305020000		.053	.002	.014	3.793
305022000		NEG	NEG	NEG	.048
305024000		NEG	NEG	NEG	.009
305025000		.032	NEG	.010	.596
305999000		.018	.011	.024	.239

MSCC	Source Category	Charge Rate Unit
305000000	Mineral Products	
305002000	Asphaltic concrete	Tons/yr
305003000	Brick manufacturing	Tons/yr
305005000	Castable refractory	Tons/yr
305006000	Cement manufacturing, dry	N. A.
305007000	Cement manufacturing, wet	N. A.
305008000	Ceramic/clay manufacturing	Tons/yr
305009000	Clay/fly ash sinter	Tons/yr
305010000	Coal cleaning	Tons/yr
305014000	Glass manufacturing	Tons/yr
305015000	Gypsum manufacturing	Tons/yr
305016000	Lime manufacturing	Tons/yr
305018000	Perlite manufacturing	Tons/yr
305020000	Stone quarry process	Tons/yr
305022000	Potash production	Tons/yr
305024000	Magnesium carbinate	Tons/yr
305025000	Sand and gravel processing	Tons/yr
305999000	Miscellaneous mineral products	N. A.

Table 1-5-a. SUMMARY OF 1977 EMISSIONS AND CHARGE RATES (Continued)

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                              SUMMARY OF MAJOR CATEGORIES
                         INDUSTRIAL PROCESS, PETROLEUM PRODUCTS                       PAGE  1
ANNUAL CHARGE RATES AND EMISSIONS PROJECTED TO 1977      RUN DATE= NOV 16,1977
 MODIFIED        TACRP
   SCC        (SCC UNITS)           EMISSIONS (MILLIONS OF TONS / YEAR)
                               NOX          HC           CO          PART
306000000                      .487         .426       15.071        .279

306001000                      .435         .049         .036        .090
306002000     1576000.         .053         .174       14.959        .161
306003000       93100.         NEG          .004         .177        NEG
306008000    27690000.         NEG          .198         NEG         NEG
306012000      114000.         NEG          NEG          NEG         .028
```

MSCC	Source Category	Charge Rate Unit
306000000	Petroleum Industry	
306001000	Process heater	N.A.[a]
306002000	Fluid catalytic crackers	1000 bbl/yr
306003000	Moving bed catalytic crackers	1000 bbl/yr
306008000	Miscellaneous leakage	1000 bbl capacity/yr
306012000	Fluid coking	1000 bbl feed/yr

[a] N.A. (not applicable) is listed under "Charge Rate Unit" where the MSCC number is made up of two or more MSCCs whose charge rates are different.

Table 1-5-a. SUMMARY OF 1977 EMISSIONS AND CHARGE RATES (Continued)

```
                              SUMMARY OF MAJOR CATEGO IES
                          INDUSTRIAL PROCESS, WOOD P=ODUCTS                 PAGE  1
ANNUAL CHARGE RATES ANE EMISSIONS PROJECTED TO 1977    RUN DATE= NOV 15,1977
 MODIFIED        TACRF                   EMISSIONS (MILLIONS OF TONS / YEAR)
   SCC        (SCC UNITS)          NOX          HC           CO           PART
307000000
                                   .008         .027         .664         .331

307001000                          .005         .005         .637         .273
307002000                          .000          NEG         .025         .007
307004000         11132000.         NEG         .009          NEG         .001
307006000           447000.         NEG         .001          NEG          NEG
307007000         62520000.        .003         .006         .001         .022
307008000        161900000.         NEG         .001         .001         .021
307020000          2525000.         NEG         .004          NEG         .007
307999000                0.        0.000        0.000        0.000        0.000
```

MSCC	Source Category	Charge Rate Unit
307000000	Wood Products	
307001000	Sulfate pulping	Tons/yr, air dried
307002000	Sulfite pulping	Tons/yr, air dried
307004000	Pulpboard mfg.	Tons/yr
307006000	Tall oil/rosin	Tons/yr
307007000	Plywood/particle board	Tons/yr
307008000	Sawmill operations	Tons/yr
307020000	Furniture manufacturing	Tons/yr
307999000	Miscellaneous wood products	Tons/yr

Table 1-5-a. SUMMARY OF 1977 EMISSIONS AND CHARGE RATES (Continued)

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                              SUMMARY OF MAJOR CATEGORIES
                               HYDROCARBON EVAPORATION
                                                                              PAGE  1
ANNUAL CHARGE RATES AND EMISSIONS PROJECTED TO 1977        RUN DATE= NOV 16,1977
 MODIFIED        TACRF           EMISSIONS (MILLIONS OF TONS / YEAR)
   SCC       (SCC UNITS)      NOX          HC            CO            PART
400000000
                              NEG         3.839          NEG           .011
401000000
                              NEG          .129          NEG           NEG
401001000          42080.     NEG          .003          NEG           NEG
401002000         114480.     NEG          .103          NEG           NEG
401999000         118650.     NEG          .023          NEG           NEG
```

MSCC	Source Category	Charge Rate Unit[a]
400000000	Point Source Evaporation	N. A
401000000	Cleaning Solvents	N. A.
401001000	Dry cleaning	Clothes, tons/yr
401002000	Degreasing	Solvent, tons/yr
401999000	Miscellaneous solvent use	Solvent, tons/yr

[a] N. A. (not applicable) is listed under "Charge Rate Unit" where the MSCC number is made up of two or more MSCCs whose charge rates are different.

Table 1-5-a. SUMMARY OF 1977 EMISSIONS AND CHARGE RATES (Continued)

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                              SUMMARY OF MAJOR CATEGORIES
                                HYDROCARBON EVAPORATION                            PAGE  2
ANNUAL CHARGE RATES AND EMISSIONS PROJECTED TO 1977      RUN DATE= NOV 16,1977
 MODIFIED          TACRF                  EMISSIONS (MILLIONS OF TONS / YEAR)
   SCC          (SCC UNITS)          NOX            HC             CO             PART

402000000        14881000.           NEG          2.003           NEG             .011

402001000          470730.           NEG           .215           NEG              NEG
402002000         9437500.           NEG           .411           NEG              NEG
402003000          299730.           NEG           .178           NEG              NEG
402004000           80186.           NEG           .053           NEG              NEG
402005000          315150.           NEG           .163           NEG              NEG
402006000          959730.           NEG           .461           NEG              NEG
402007000         1597500.           NEG           .231           NEG              NEG
402008000          180700.           NEG           .099           NEG              NEG
402999000         1539400.           NEG           .192           NEG             .011
```

MSCC	Source Category	Charge Rate Unit
402000000	Surface Coating	Coating, tons/yr
402001000	Paint	Coating, tons/yr
402002000	Paper coatings	Coating, tons/yr
402003000	Varnish and shellac	Coating, tons/yr
402004000	Lacquer	Coating, tons/yr
402005000	Enamel	Coating, tons/yr
402006000	Primer	Coating, tons/yr
402007000	Fabric coatings	Coating, tons/yr
402008000	Oven coatings	Coating, tons/yr
402999000	Miscellaneous coatings	Coating, tons/yr

Table 1-5-a. SUMMARY OF 1977 EMISSIONS AND CHARGE RATES (Continued)

```
                                   SUMMARY OF MAJOR CATEGORIES
                                    HYDROCARBON EVAPORATION                               PAGE   5
ANNUAL CHARGE RATES AND EMISSIONS PROJECTED TO 1977          RUN DATE= NOV 16,1977
 MODIFIED          IACRP                    EMISSIONS (MILLIONS OF TONS / YEAR)
   SCC          (SCC UNITS)         NOX             HC              CO            PART
403000000
                                    NEG           1.351            NEG            NEG

403001000                           NEG           1.007            NEG            NEG
403002000                           NEG            .194            NEG            NEG
403003000        18360000.          NEG            .081            NEG            NEG
403999000        15000000.          NEG            .069            NEG            NEG

406000000       199790000.          NEG            .357            NEG            NEG

406001000        82154000.          NEG            .210            NEG            NEG
406002000       117600000.          NEG            .147            NEG            NEG
```

MSCC	Source Category	Charge Rate Unit[a]
403000000	Petroleum Storage	N. A.
403001000	Fixed roof	N. A.
403002000	Floating roof	N. A.
403003000	Variable vapor space	1000 gal/yr
403999000	Miscellaneous storage	1000 gal/yr
406000000	Petroleum Marketing and Transportation	1000 gal/yr
406001000	Rail and truck transportation	1000 gal/yr
406002000	Marine vessel transportation	1000 gal/yr

[a] N. A. (not applicable) is listed under "Charge Rate Unit" where the MSCC number is made up of two or more MSCCs whose charge rates are different.

Table 1-5-b. SUMMARY OF 1977 EMISSION AND CHARGE RATES UNCERTAINTY

```
                              SUMMARY OF MAJOR CATEGORIES
                        EXTERNAL COMBUSTION, BOILER CATEGORY                  PAGE  1
TACR AND EMISSION UNCERTAINTIES PROJECTED TO 1977         RUN DATE= NOV 16,1977
 MODIFIED          TACR                       EMISSIONS (MILLIONS OF TONS / YEAR)
   SCC          (SCC UNITS)          NOX               HC               CO               PART
100000000                         +  .522          +  .112          +  .090          +  .595
                                  -  .512          -  .025          -  .061          -  .594

101000000                         +  .491          +  .111          +  .080          +  .539
                                  -  .473          -  .017          -  .053          -  .538

101002000     +     9195800.      +  .449          +  .110          +  .077          +  .538
              -     9146500.      -  .449          -  .016          -  .052          -  .538
101004000     +     4911500.      +  .195          +  .011          +  .017          +  .020
              -     3609100.      -  .141          -  .008          -  .011          -  .014
101005000     +          0.       + 0.000          + 0.000          + 0.000          + 0.000
              -          0.       - 0.000          - 0.000          - 0.000          - 0.000
101006000     +      127590.      +  .039          +  .001          +  .009          +  .001
              -      125150.      -  .039          -  .000          -  .006          -  .001
101007000     +       15220.      +  .000             NEG              NEG              NEG
              -       15220.      -  .000             NEG              NEG              NEG
```

MSCC	Source Category	Charge Rate Unit
100000000	External Combustion (Boiler)	
101000000	Electric Generation	
101002000	Bituminous coal	Tons burned/yr
101004000	Residual oil	1000 gal/yr
101005000	Distillate oil	1000 gal/yr
101006000	Natural gas	Million cu ft/yr
101007000	Process gas	Million cu ft/yr

Table 1-5-b. SUMMARY OF 1977 EMISSION AND CHARGE RATES UNCERTAINTY (Continued)

```
                               SUMMARY OF MAJOR CATEGORIES
                        EXTERNAL COMBUSTION, BOILER CATEGORY                      PAGE  2
 TACF AND EMISSION UNCERTAINTIES PROJECTED TO 1977          RUN DATE= NOV 16,1977
  MODIFIED           TACRF                     EMISSIONS (MILLIONS OF TONS / YEAR)
    SCC           (SCC UNITS)         NOX                HC                CO               PART
 102000000
                                    +  .177          +  .021          +  .041          +  .252
                                    -  .197          -  .018          -  .030          -  .252

 102002000      +     2283400.      +  .092          +  .015          +  .032          +  .252
                -     2283400.      -  .092          -  .015          -  .023          -  .252
 102004000      +      705210.      +  .125          +  .013          +  .016          +  .008
                -      705210.      -  .125          -  .008          -  .013          -  .008
 102005000      +      198130.      +  .046          +  .005          +  .006          +  .001
                -      198130.      -  .046          -  .003          -  .004          -  .001
 102006000      +      198130.      +  .072          +  .004          +  .020          +  .002
                -      198130.      -  .112          -  .002          -  .013          -  .002
 102007000      +      142990.      +  .000              NEG              NEG              NEG
                -      142990.      -  .000              NEG              NEG              NEG
```

MSCC	Source Category	Charge Rate Unit
102000000	Industrial	
102002000	Bituminous coal	Tons burned/yr
102004000	Residual oil	1000 gal/yr
102005000	Distillate oil	1000 gal/yr
102006000	Natural gas	Million cu ft/yr
102007000	Process gas	Million cu ft/yr

Table 1-5-b. SUMMARY OF 1977 EMISSION AND CHARGE RATES UNCERTAINTY (Continued)

```
                          SUMMARY OF MAJOR CATEGORIES
                          INTERNAL COMBUSTION ENGINES                       PAGE  1
TACR AND EMISSION UNCERTAINTIES PROJECTED TO 1977          RUN DATE= NOV 16,1977
 MODIFIED        TACRP                EMISSIONS (MILLIONS OF TONS / YEAR)
   SCC        (SCC UNITS)        NOX             HC              CO             PART
200000000
                              +  .400         +  .210         +  .039        +  .025
                              -  .151         -  .073         -  .014        -  .009
201000000
                              +  .381         +  .018         +  .030        +  .025
                              -  .130         -  .017         -  .010        -  .008

201001000    +     3364000.   +  .374         +  .005         +  .030        +  .025
             -     1163100.   -  .129         -  .002         -  .010        -  .008
201002000    +      418290.   +  .073         +  .002         +  .003        +  .001
             -      113670.   -  .022         -  .001         -  .000        -  .000
201003000    +       16026.   +  .003         +  .000         +  .002        +  .001
             -       16026.   -  .002         -  .000         -  .001        -  .001
201999000                     +  .004         +  .017         +  .000        +  .001
                              -  .004         -  .017         -  .000        -  .001
```

MSCC	Source Category	Charge Rate Unit[a]
200000000	Internal Combustion	
201000000	Electric Generation	
201001000	Distillate oil	1000 gal/yr
201002000	Natural gas	Million cu ft/yr
201003000	Diesel	1000 gal/yr
201999000	Miscellaneous fuel	N.A.[a]

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[a] N.A. (not applicable) is listed under "Charge Rate Unit" where the MSCC number is made up of two or more MSCCs whose charge rates are different.

Table 1-5-b. SUMMARY OF 1977 EMISSION AND CHARGE RATES UNCERTAINTY (Continued)

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                           SUMMARY OF MAJOR CATEGORIES
                          INTERNAL COMBUSTION ENGINES                         PAGE  2
 TACR AND EMISSION UNCERTAINTIES PROJECTED TO 1977          RUN DATE= NOV 16,1977
  MODIFIED         TACRP               EMISSIONS (MILLIONS OF TONS / YEAR)
    SCC         (SCC UNITS)          NOX             HC              CO              PART
 202000000
                                  +  .121         +  .209         +  .025         +  .005
                                  -  .076         -  .071         -  .010         -  .004

 202001000     +       33032.     +  .002         +  .000         +  .001         +  .000
               -       33032.     -  .002         -  .000         -  .001         -  .000
 202002000     +      631400.     +  .121         +  .032         +  .024         +  .005
               -      211690.     -  .076         -  .019         -  .010         -  .004
 202003000     +        1626.     +  .000         +  .000         +  .003         +  .000
               -        1626.     -  .000         -  .000         -  .001         -  .000
 202004000.    +       26177.     +  .005         +  .000         +  .002         +  .000
               -       26177.     -  .005         -  .000         -  .002         -  .000
 202999000     +        9453.     +  .001         +  .207         +  .000         +  .000
               -        9453.     -  .001         -  .068         -  .000         -  .000
```

MSCC	Source Category	Charge Rate Unit
202000000	Industrial IC Engines	
202001000	Distillate oil turbine	1000 gal/yr
202002000	Distillate oil reciprocating	1000 gal/yr
202003000	Natural gas turbine	Million cu ft/yr
202004000	Natural gas reciprocating	Million cu ft/yr
202999000	Miscellaneous fuels[a]	Million cu ft/yr

Table 1-5-b. SUMMARY OF 1977 EMISSION AND CHARGE RATES UNCERTAINTY (Continued)

```
                              SUMMARY OF MAJOR CATEGORIES
                       INDUSTRIAL PROCESS, CHEMICAL MANUFACTURING              PAGE  1
TACR AND EMISSION UNCERTAINTIES PROJECTED TO 1977         RUN DATE= NOV 16,1977
 MODIFIED         TACRF                      EMISSIONS (MILLIONS OF TONS / YEAR)
   SCC         (SCC UNITS)           NOX                HC                CO               PART
301000000
                                     NEG         +   .103        +   .377                  NEG
                                     NEG         -   .103        -   .377                  NEG
301002000    +      239590.          NEG         +   .029        +   .001                  NEG
             -      239590.          NEG         -   .029        -   .001                  NEG
301003000    +       56997.          NEG         +   .004        +   .033                  NEG
             -       56997.          NEG         -   .004        -   .033                  NEG
301005000    +      228300.          NEG         +   .074        +   .353                  NEG
             -      228300.          NEG         -   .074        -   .352                  NEG
301999000    +    17464000.          NEG         +   .065        +   .129                  NEG
             -    17464000.          NEG         -   .065        -   .129                  NEG
```

MSCC	Source Category	Charge Rate Unit
300000000	Industrial Processes	
301000000	Chemical Manufacturing	
301002000	Ammonia production with methanator	Tons/yr
301003000	Ammonia production with CO absorber	Tons/yr
301005000	Carbon black production	Tons/yr
301999000	Miscellaneous chemical manufacturing	Tons/yr

Table 1-5-b. SUMMARY OF 1977 EMISSION AND CHARGE RATES UNCERTAINTY (Continued)

```
                         SUMMARY OF MAJOR CATEGORIES
                    INDUSTRIAL PROCESS, PRIMARY METALS                        PAGE  1
TACR AND EMISSION UNCERTAINTIES PROJECTED TO 1977         RUN DATE= NOV 16,1977
 MODIFIED        TACRP                  EMISSIONS (MILLIONS OF TONS / YEAR)
   SCC        (SCC UNITS)         NOX           HC            CO             PART
303000000
                               + .002       + .022       + 1.582       +  .345
                               - .010       - .064       - 1.583       -  .256

303001000   +     8849400.       NEG          NEG           NEG        +  .191
            -     3948800.       NEG          NEG           NEG        -  .042
303002000   +      723290.       NEG          NEG           NEG        +  .029
            -      723290.       NEG          NEG           NEG        -  .037
303003000   +    31887000.   +  .000       + .021       +  .006        +  .034
            -    31887000.   -  .001       - .064       -  .028        -  .035
303004000   +      135720.       NEG       + .001       +  .000        +  .036
            -      135720.       NEG       - .001       -  .000        -  .029
303005000                        NEG          NEG           NEG        +  .053
                                 NEG          NEG           NEG        -  .056
303006000   +     1056600.       NEG          NEG           NEG        +  .119
            -     1055800.       NEG          NEG           NEG        -  .081
303007000   +      641890.       NEG          NEG           NEG        +  .002
            -      641890.       NEG          NEG           NEG        -  .002
```

MSCC	Source Category	Charge Rate Unit[a]
303000000	Primary Metals	N. A.
303001000	Aluminum reduction	Aluminum, tons/yr
303002000	Aluminum ore calcined	Tons/yr
303003000	Coke metallurgical	Coal, tons/yr
303004000	Coke beehive	Coal, tons/yr
303005000	Copper smelters	N. A.
303006000	Ferroalloy production (open furnace)	Tons/yr
303007000	Ferroalloy production (closed furnace)	

[a] N. A. (not applicable) is listed under "Charge Rate Unit" where the MSCC number is made up of two or more MSCCs whose charge rates are different.

Table 1-5-b. SUMMARY OF 1977 EMISSION AND CHARGE RATES UNCERTAINTY (Continued)

```
                            SUMMARY OF MAJOR CATEGORIES
                        INDUSTRIAL PROCESS, PRIMARY METALS                    PAGE  2
TACR AND EMISSION UNCERTAINTIES PROJECTED TO 1977        RUN DATE= NOV 16,1977
 MODIFIED           TACRF                EMISSIONS (MILLIONS OF TONS / YEAR)
   SCC           (SCC UNITS)          NOX             HC             CO              PART
303008000                             NEG             NEG        + 1.151          + .247
                                      NEG             NEG        - 1.151          - .222
303009000    +    14310000.      +   .002      +   .002        + 1.085          + .031
             -    14310000.      -   .010      -   .008        - 1.086          - .033
303010000    +     1116500.      +   .000      +   .000             NEG          + .003
             -     1116500.      -   .000      -   .000             NEG          - .005
303011000                             NEG             NEG            NEG          + .003
                                      NEG             NEG            NEG          - .004
303012000    +       11661.           NEG             NEG        +  .002            NEG
             -       11661.           NEG             NEG        -  .001            NEG
303030000    +      219140.           NEG             NEG            NEG          + .002
             -      219140.           NEG             NEG            NEG          - .002
303999000    +     5000000.      +   .000      +   .000        +  .000          + .009
             -     5000000.      -   .001      -   .001        -  .001          - .009
```

MSCC	Source Category	Charge Rate Unit[a]
303008000	Iron production	N. A.
303009000	Steel production	Tons/yr
303010000	Lead smelters	N. A.
303011000	Molybdenum	N. A.
303012000	Titanium	N. A.
303030000	Zinc smelting	Tons/yr
303999000	Miscellaneous metallurgical processes	Tons/yr

[a] N. A. (not applicable) is listed under "Charge Rate Unit" where the MSCC number is made up of two or more MSCCs whose charge rates are different.

Table 1-5-b. SUMMARY OF 1977 EMISSION AND CHARGE RATES UNCERTAINTY (Continued)

```
                              SUMMARY OF MAJOR CATEGORIES
                         INDUSTRIAL PROCESS, SECONDARY METALS                  PAGE  1a
 TACR AND EMISSION UNCERTAINTIES PROJECTED TO 1977        RUN DATE= NOV 16,1977
 MODIFIED          TACRF                    EMISSIONS (MILLIONS OF TONS / YEAR)
   SCC          (SCC UNITS)          NOX                 HC                CO              PART
 304000000
                                  +  .003          +   .001         +   .131        +   .050
                                  -  .009          -   .003         -   .131        -   .056

 304001000     +     116990.      +  .000          +   .000              NEG        +   .001
               -     116990.      -  .000          -   .001              NEG        -   .001
 304002000     +      24625.      +  .000          +   .000              NEG        +   .001
               -      24625.      -  .000          -   .000              NEG        -   .001
 304003000     +    3073600.      +  .000          +   .000         +   .131        +   .013
               -    3073600.      -  .000          -   .001         -   .131        -   .021
 304004000     +      27123.          NEG          +   .000              NEG        +   .000
               -      27123.          NEG          -   .000              NEG        -   .000
 304006000     +       1979.          NEG               NEG         +   .000            NEG
               -       1979.          NEG               NEG         -   .000            NEG
```

MSCC	Source Category	Charge Rate Unit
304000000	Secondary Metals	
304001000	Aluminum operations	Tons/yr
304002000	Brass/bronze melt	Tons/yr
304003000	Gray iron	Tons/yr
304004000	Secondary lead smelting	Tons/yr
304006000	Secondary magnesium	Tons/yr

Table 1-5-b. SUMMARY OF 1977 EMISSION AND CHARGE RATES UNCERTAINTY (Continued)

```
                               SUMMARY OF MAJOR CATEGORIES
                          INDUSTRIAL PROCESS, SECONDARY METALS                    PAGE  1b
TACR AND EMISSION UNCERTAINTIES PROJECTED TO 1977        RUN DATE= NOV 16,1977
 MODIFIED          TACRF                  EMISSIONS (MILLIONS OF TONS / YEAR)
   SCC          (SCC UNITS)          NOX             HC              CO              PART
304007000    +    6209800.      +   .003      +   .001      +   .011      +   .046
             -    6209800.      -   .009      -   .002      -   .004      -   .051
304008000    +      63268.          NEG       +   .001          NEG       +   .001
             -      63268.          NEG       -   .001          NEG       -   .002
304009000    +     171600.          NEG           NEG       +   .005      +   .000
             -     171600.          NEG           NEG       -   .005      -   .000
304010000    +       4104.          NEG           NEG       +   .001          NEG
             -       4104.          NEG           NEG       -   .001          NEG
304020000    +      59095.          NEG           NEG           NEG       +   .000
             -      59095.          NEG           NEG           NEG       -   .000
304050000    +     345400.          NEG       +   .000          NEG       +   .001
             -     345400.          NEG       -   .001          NEG       -   .001
304999000    +    2250000.      +   .001      +   .000          NEG       +   .005
             -    2250000.      -   .001      -   .001          NEG       -   .003
```

MSCC	Source Category	Charge Rate Unit
304007000	Steel foundry	Tons/yr
304008000	Secondary zinc	Tons/yr
304009000	Malleable iron	Tons/yr
304010000	Nickel	Tons/yr
304020000	Furnace electrodes	Tons/yr
304050000	Misc. casting & fabrication	Tons/yr
304999000	Misc. secondary metal activity	Tons/yr

Table 1-5-b. SUMMARY OF 1977 EMISSION AND CHARGE RATES UNCERTAINTY (Continued)

```
                         SUMMARY OF MAJOR CATEGORIES
                   INDUSTRIAL PROCESS, MINERAL PRODUCTS                     PAGE  1
TACR AND EMISSION UNCERTAINTIES PROJECTED TO 1977       RUN DATE= NOV 16,1977
 MODIFIED       TACRF                EMISSIONS (MILLIONS OF TONS / YEAR)
   SCC       (SCC UNITS)         NOX            HC             CO          PART
305000000
                              + .041         + .003         + .007      + 1.010
                              - .022         - .003         - .007      - 1.049
305002000
                              + .009         + .000         + .001      +  .241
305003000                     - .009         - .000         - .001      -  .294
                                 NEG            NEG            NEG      +  .099
305005000                        NEG            NEG            NEG      -  .098
                                 NEG            NEG            NEG      +  .001
305006000                        NEG            NEG            NEG      -  .001
                              + .008            NEG            NEG      +  .257
305007000                     - .008            NEG            NEG      -  .280
                              + .006            NEG            NEG      +  .275
305008000                     - .011            NEG            NEG      -  .298
                              + .000            NEG         + .000      +  .037
305009000                     - .000            NEG         - .000      -  .040
                                 NEG            NEG            NEG      +  .004
                                 NEG            NEG            NEG      -  .004
```

MSCC	Source Category	Charge Rate Unit[a]
305000000	Mineral Products	
305002000	Asphaltic concrete	Tons/yr
305003000	Brick manufacturing	Tons/yr
305005000	Castable refractory	Tons/yr
305006000	Cement mfg., dry	N. A.
305007000	Cement mfg., wet	N. A.
305008000	Ceramic/clay mfg.	Tons/yr
305009000	Clay/fly ash sinter	Tons/yr

[a] N. A (not applicable) is listed under "Charge Rate Unit" where the MSCC number is made up of two or more MSCCs whose charge rates are different.

Table 1-5-b. SUMMARY OF 1977 EMISSION AND CHARGE RATES UNCERTAINTY (Continued)

```
                              SUMMARY OF MAJOR CATEGORIES
                         INDUSTRIAL PROCESS, MINERAL PRODUCTS                         PAGE  2
TACR AND EMISSION UNCERTAINTIES PROJECTED TO 1977          RUN DATE= NOV 16,1977
 MODIFIED        TACRP               EMISSIONS (MILLIONS OF TONS / YEAR)
   SCC        (SCC UNITS)        NOX            HC              CO              PART
305010000
                             +  .001           NEG        +  .000         +  .024
305014000                    -  .001           NEG        -  .000         -  .033
                             +  .005           NEG           NEG          +  .002
305015000                    -  .005           NEG           NEG          -  .002
                             +  .036           NEG           NEG          +  .028
305016000                    -  .001           NEG           NEG          -  .033
                             +  .000      +  .000         +  .000         +  .180
305018000                    -  .000      -  .000         -  .000         -  .208
                                NEG           NEG            NEG          +  .001
305020000                       NEG           NEG            NEG          -  .001
                             +  .012      +  .001         +  .004         +  .864
305022000                    -  .012      -  .001         -  .004         -  .872
                                NEG           NEG            NEG          +  .016
305024000                       NEG           NEG            NEG          -  .016
                                NEG           NEG            NEG          +  .002
305025000                       NEG           NEG            NEG          -  .002
                             +  .007           NEG        +  .002         +  .163
                             -  .007           NEG        -  .002         -  .163
305999000
                             +  .005      +  .003         +  .006         +  .063
                             -  .005      -  .003         -  .006         -  .063
```

MSCC	Source Category	Charge Rate Unit
305010000	Coal cleaning	Tons/yr
305014000	Glass manufacturing	Tons/yr
305015000	Gypsum manufacturing	Tons/yr
305016000	Lime manufacturing	Tons/yr
305018000	Perlite manufacturing	Tons/yr
305020000	Stone quarry process	Tons/yr
305022000	Potash production	Tons/yr
305024000	Magnesium carbinate	Tons/yr
305025000	Sand and gravel processing	Tons/yr
305999000	Miscellaneous mineral products	N. A.

Table 1-5-b. SUMMARY OF 1977 EMISSION AND CHARGE RATES UNCERTAINTY (Continued)

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                           SUMMARY OF MAJOR CATEGORIES
                    INDUSTRIAL PROCESS, PETROLEUM PRODUCTS                  PAGE  1
 TACR AND EMISSION UNCERTAINTIES PROJECTED TO 1977      RUN DATE= NOV 16,1977
 MODIFIED          TACRP                 EMISSIONS (MILLIONS OF TONS / YEAR)
   SCC          (SCC UNITS)          NOX            HC              CO            PART
 306000000                         +  .027       +  .038       + 6.216       +  .012
                                   -  .027       -  .039       - 6.216       -  .012

 306001000                         +  .027       +  .006       +  .005       +  .005
                                   -  .027       -  .006       -  .005       -  .005
 306002000    +        72971.      +  .004       +  .012       + 6.216       +  .011
              -        72971.      -  .004       -  .012       - 6.216       -  .011
 306003000    +         8633.         NEG        +  .000       +  .019          NEG
              -         8633.         NEG        -  .000       -  .019          NEG
 306008000    +       590690.         NEG        +  .036          NEG           NEG
              -       590690.         NEG        -  .036          NEG           NEG
 306012000    +         5205.         NEG           NEG           NEG        +  .002
              -         5205.         NEG           NEG           NEG        -  .002
```

MSCC	Source Category	Charge Rate Unit[a]
306000000	Petroleum Industry	
306001000	Process heater	N.A.
306002000	Fluid catalytic crackers	1000 bbl/yr
306003000	Moving bed catalytic crackers	1000 bbl/yr
306008000	Miscellaneous leakage	1000 bbl capacity/yr
306012000	Fluid coking	1000 bbl feed/yr

[a] N.A. (not applicable) is listed under "Charge Rate Unit" where the MSCC number is made up of two or more MSCCs whose charge rates are different.

Table 1-5-b. SUMMARY OF 1977 EMISSION AND CHARGE RATES UNCERTAINTY (Continued)

```
                            SUMMARY OF MAJOR CATEGORIES
                         INDUSTRIAL PROCESS, WOOD PRODUCTS                          PAGE  1
TACR AND EMISSION UNCERTAINTIES PROJECTED TO 1977          RUN DATE= NOV 16,1977
 MODIFIED         TACRP                 EMISSIONS (MILLIONS OF TONS / YEAR)
   SCC        (SCC UNITS)          NOX            HC             CO            PART
307000000                       +  .038       +  .002       +  .397       +  .172
                                -  .003       -  .002       -  .397       -  .202
307001000                       +  .038       +  .001       +  .397       +  .172
                                -  .003       -  .001       -  .397       -  .201
307002000                       +  .000          NEG        +  .002       +  .001
                                -  .000          NEG        -  .002       -  .001
307004000    +     225620.         NEG        +  .000          NEG        +  .000
             -     225620.         NEG        -  .000          NEG        -  .000
307006000    +      50062.         NEG        +  .000          NEG           NEG
             -      50062.         NEG        -  .000          NEG           NEG
307007000    +     218630.      +  .000       +  .000       +  .000       +  .003
             -     218630.      -  .000       -  .000       -  .000       -  .003
307008000    +          0.         NEG        + 0.000       + 0.000       + 0.000
             -          0.         NEG        - 0.000       - 0.000       -  .017
307020000    +     200000.         NEG        +  .000          NEG        +  .001
             -     200000.         NEG        -  .000          NEG        -  .001
307999000    +          0.      + 0.000       + 0.000       + 0.000       + 0.000
             -          0.      - 0.000       - 0.000       - 0.000       - 0.000
```

MSCC	Source Category	Charge Rate Unit
307000000	Wood Products	
307001000	Sulfate pulping	Tons/yr, air dried
307002000	Sulfite pulping	Tons/yr, air dried
307004000	Pulpboard mfg.	Tons/yr
307006000	Tall oil/rosin	Tons/yr
307007000	Plywood/particle board	Tons/yr
307008000	Sawmill operations	Tons/yr
307020000	Furniture manufacturing	Tons/yr
307999000	Miscellaneous wood products	Tons/yr

Table 1-5-b. SUMMARY OF 1977 EMISSION AND CHARGE RATES UNCERTAINTY (Continued)

```
                                 SUMMARY OF MAJOR CATEGORIES
                                  HYDROCARBON EVAPORATION                          PAGE  1
TACR AND EMISSION UNCERTAINTIES PROJECTED TO 1977          RUN DATE= NOV 15,1977
 MODIFIED          TACRE              EMISSIONS (MILLIONS OF TONS / YEAR)
   SCC         (SCC UNITS)         NOX            HC             CO           PART
400000000
                                   NEG      +  .533            NEG       +  .002
                                   NEG      -  .441            NEG       -  .002

401000000                          NEG      +  .059            NEG             NEG
                                   NEG      -  .059            NEG             NEG

401001000     +     25904.         NEG      +  .004            NEG             NEG
              -     15296.         NEG      -  .002            NEG             NEG
401002000     +     60930.         NEG      +  .058            NEG             NEG
              -     60930.         NEG      -  .059            NEG             NEG
401999000     +     20907.         NEG      +  .005            NEG             NEG
              -     20907.         NEG      -  .005            NEG             NEG
```

MSCC	Source Category	Charge Rate Unit[a]
400000000	Point Source Evaporation	N. A.
401000000	Cleaning Solvents	N. A.
401001000	Dry cleaning	Clothes, tons/yr
401002000	Degreasing	Solvent, tons/yr
401999000	Miscellaneous solvent use	Solvent, tons/yr

[a] N. A. (not applicable) is listed under "Charge Rate Unit" where the MSCC number is made up of two or more MSCCs whose charge rates are different.

Table 1-5-b. SUMMARY OF 1977 EMISSION AND CHARGE RATES UNCERTAINTY (Continued)

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                                   SUMMARY OF MAJOR CATEGORIES

                                     HYDROCARBON EVAPORATION                              PAGE  2
TACR AND EMISSION UNCERTAINTIES PROJECTED TO 1977          RUN DATE= NOV 16,1977
 MODIFIED        TACRF                       EMISSIONS (MILLIONS OF TONS / YEAR)
   SCC        (SCC UNITS)           NOX             HC               CO                PART
402000000   +     3936200.          NEG        +   .282             NEG            +   .002
            -     3308100.          NEG        -   .262             NEG            -   .002

402001000   +  [illegible]          NEG        +   .036             NEG                NEG
            -  [illegible]          NEG        -   .036             NEG                NEG
402002000   +   39[illegible]       NEG        +   .217             NEG                NEG
            -   38[illegible]       NEG        -   .189             NEG                NEG
402003000   +       31425.          NEG        +   .027             NEG                NEG
            -       31425.          NEG        -   .027             NEG                NEG
402004000   +       13532.          NEG        +   .011             NEG                NEG
            -       13532.          NEG        -   .011             NEG                NEG
402005000   +       53907.          NEG        +   .031             NEG                NEG
            -       53907.          NEG        -   .031             NEG                NEG
402006000   +      102430.          NEG        +   .113             NEG                NEG
            -      102430.          NEG        -   .113             NEG                NEG
402007000   +      106670.          NEG        +   .120             NEG                NEG
            -      106670.          NEG        -   .122             NEG                NEG
402008000   +       33707.          NEG        +   .021             NEG                NEG
            -       33707.          NEG        -   .021             NEG                NEG
402999000   +      287690.          NEG        +   .044             NEG            +   .002
            -      287690.          NEG        -   .044             NEG            -   .002
```

MSCC	Source Category	Charge Rate Unit
402000000	Surface Coating	Coating, tons/yr
402001000	Paint	Coating, tons/yr
402002000	Paper coatings	Coating, tons/yr
402003000	Varnish and shellac	Coating, tons/yr
402004000	Lacquer	Coating, tons/yr
402005000	Enamel	Coating, tons/yr
402006000	Primer	Coating, tons/yr
402007000	Fabric coatings	Coating, tons/yr
402008000	Oven coatings	Coating, tons/yr
402999000	Miscellaneous coatings	Coating, tons/yr

Table 1-5-b. SUMMARY OF 1977 EMISSION AND CHARGE RATES UNCERTAINTY (Continued)

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                                SUMMARY OF MAJOR CATEGORIES
                                 HYDROCARBON EVAPORATION                              PAGE   3
TACR AND EMISSION UNCERTAINTIES PROJECTED TO 1977         RUN DATE= NOV 16,1977
 MODIFIED           TACRP                      EMISSIONS (MILLIONS OF TONS / YEAR)
   SCC           (SCC UNITS)            NOX                HC              CO             PART
403000000
                                        NEG          +   .437            NEG              NEG
                                        NEG          -   .337            NEG              NEG
403001000
                                        NEG          +   .425            NEG              NEG
403002000                               NEG          -   .321            NEG              NEG
                                        NEG          +   .089            NEG              NEG
403003000      +       458910.          NEG          -   .085            NEG              NEG
               -       458910.          NEG          +   .014            NEG              NEG
403999000      +     10198000.          NEG          -   .016            NEG              NEG
               -     10198000.          NEG          +   .047            NEG              NEG
                                        NEG          -   .058            NEG              NEG
```

MSCC	Source Category	Charge Rate Unit[a]
403000000	Petroleum Storage	N. A
403001000	Fixed roof	N. A.
403002000	Floating roof	N. A.
403003000	Variable vapor space	1000 gal/yr
403999000	Miscellaneous storage	1000 gal/yr

[a] N. A (not applicable) is listed under "Charge Rate Unit" where the MSCC number is made up of two or more MSCCs whose charge rates are different.

Table 1-5-b. SUMMARY OF 1977 EMISSION AND CHARGE RATES UNCERTAINTY (Continued)

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                                    SUMMARY OF MAJOR CATEGORIES
                                     HYDROCARBON EVAPORATION                              PAGE  4
TACR AND EMISSION UNCERTAINTIES PROJECTED TO 1977        RUN DATE= NOV 16,1977
 MODIFIED           TACRP                       EMISSIONS (MILLIONS OF TONS / YEAR)
   SCC           (SCC UNITS)           NOX                 HC            CO             PART
406000000     +    21351000.           NEG        +   .100             NEG             NEG
              -    21350000.           NEG        -   .093             NEG             NEG

406001000     +     8773700.           NEG        +   .093             NEG             NEG
              -     8773000.           NEG        -   .085             NEG             NEG
406002000     +    19465000.           NEG        +   .037             NEG             NEG
              -    19465000.           NEG        -   .039             NEG             NEG
```

MSCC	Source Category	Charge Rate Unit
406000000	Petroleum Marketing & Transportation	1000 gal/yr
406001000	Rail and truck transportation	1000 gal/yr
406002000	Marine vessel transportation	1000 gal/yr

Table 1-6-a. SUMMARY OF 1982 EMISSIONS AND CHARGE RATES

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                                 SUMMARY OF MAJOR CATEGORIES

                            EXTERNAL COMBUSTION, BOILER CATEGORY                        PAGE   1
      ANNUAL CHARGE RATES AND EMISSIONS PROJECTED TO 1982      RUN DATE= NOV 16,1977
       MODIFIED           IACRP              EMISSIONS (MILLIONS OF TONS / YEAR)
         SCC           (SCC UNITS)         NOX           HC            CO            PART
      100000000                           6.447          .243          .606          6.304

      101000000                           4.913          .130          .330          4.265

      101002000         520000000.        4.767          .099          .272          4.130
      101004000          31400000.         .115          .031          .047           .126
      101005000                0.         0.000         0.000         0.000         0.000
      101006000           1232200.         .031          .001          .010           .009
      101007000             90390.         .000           NEG           NEG           NEG

      102000000                           1.534          .119          .276          2.039

      102002000         145390000.        1.124          .066          .163          1.684
      102004000          21425000.         .073          .032          .050           .246
      102005000           7904500.         .029          .012          .016           .059
      102006000           5559000.         .303          .008          .047           .050
      102007000           1749300.         .000           NEG           NEG           NEG
```

MSCC	Source Category	Charge Rate Unit
100000000	External Combustion (Boiler)	
101000000	Electric Generation	
101002000	Bituminous coal	Tons burned/yr
101004000	Residual oil	1000 gal/yr
101005000	Distillate oil	1000 gal/yr
101006000	Natural gas	Million cu ft/yr
101007000	Process gas	Million cu ft/yr
102000000	Industrial	
102002000	Bituminous coal	Tons burned/yr
102004000	Residual oil	1000 gal/yr
102005000	Distillate oil	1000 gal/yr
102006000	Natural gas	Million cu ft/yr
102007000	Process gas	Million cu ft/yr

Table 1-6-a. SUMMARY OF 1982 EMISSIONS AND CHARGE RATES (Continued)

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                              SUMMARY OF MAJOR CATEGORIES
                              INTERNAL COMBUSTION ENGINES                          PAGE  1
ANNUAL CHARGE RATES AND EMISSIONS PROJECTED TO 1982      RUN DATE= NOV 16,1977
 MODIFIED         TACRF                  EMISSIONS (MILLIONS OF TONS / YEAR)
   SCC         (SCC UNITS)          NOX           HC           CO          PART
200000000
                                    .553          .446         .065         .019
201000000
                                    .259          .110         .019         .014
201001000       1350600.            .149          .002         .012         .010
201002000        271340.            .077          .000         .000         .000
201003000         86009.            .012          .001         .006         .002
201999000                           .020          .107         .002         .002
```

MSCC	Source Category	Charge Rate Unit[a]
200000000	Internal Combustion	
201000000	Electric Generation	
201001000	Distillate oil	1000 gal/yr
201002000	Natural gas	Million cu ft/yr
201003000	Diesel	1000 gal/yr
201999000	Miscellaneous fuel	N.A.

[a] N.A. (not applicable) is listed under "Charge Rate Unit" where the MSCC number is made up of two or more MSCCs whose charge rates are different.

Table 1-6-a. SUMMARY OF 1982 EMISSIONS AND CHARGE RATES (Continued)

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                          SUMMARY OF MAJOR CATEGORIES
                          INTERNAL COMBUSTION ENGINES                    PAGE  2
ANNUAL CHARGE RATES AND EMISSIONS PROJECTED TO 1982     RUN DATE= NOV 16,1977
 MODIFIED         TACRF              EMISSIONS (MILLIONS OF TONS / YEAR)
   SCC         (SCC UNITS)       NOX          HC           CO           PART
202000010
                                 .294         .335         .045         .005

202001000         65273.         .005         .001         .002         .001
202002000        764470.         .276         .070         .035         .003
202003000          5090.         .001         .001         .004         .000
202004000         35396.         .007         .001         .003         .000
202999000         36561.         .005         .263         .002         .000
```

MSCC	Source Category	Charge Rate Unit
202000000	Industrial IC Engines	
202001000	Distillate oil turbine	1000 gal/yr
202002000	Distillate oil reciprocating	1000 gal/yr
202003000	Natural gas turbine	Million cu ft/yr
202004000	Natural gas reciprocating	Million cu ft/yr
202999000	Miscellaneous fuels [a]	Million cu ft/yr

[a] Although this category is made up of two MSCCs whose units are different, only one (202999970) was studied.

Table 1-6-a. SUMMARY OF 1982 EMISSIONS AND CHARGE RATES (Continued)

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                         SUMMARY OF MAJOR CATEGORIES
                INDUSTRIAL PROCESS, CHEMICAL MANUFACTURING              PAGE  1
ANNUAL CHARGE RATES AND EMISSIONS PROJECTED TO 1982     RUN DATE= NOV 16,1977
 MODIFIED        IACRF           EMISSIONS (MILLIONS OF TONS / YEAR)
   SCC        (SCC UNITS)      NOX          HC           CO          PART
301000000
                               NEG         1.144        2.815        NEG

301002000       7473800.       NEG          .256         .003        NEG
301003000       2988300.       NEG          .038         .056        NEG
301005000       6282100.       NEG          .331        2.420        NEG
301999000     151180000.       NEG          .518         .336        NEG
```

MSCC	Source Category	Charge Rate Unit
300000000	Industrial Processes	
301000000	Chemical Manufacturing	
301002000	Ammonia production with methanator	Tons/yr
301003000	Ammonia production with CO absorber	Tons/yr
301005000	Carbon black production	Tons/yr
301999000	Miscellaneous chemical manufacturing	Tons/yr

Table 1-6-a. SUMMARY OF 1982 EMISSIONS AND CHARGE RATES (Continued)

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                         SUMMARY OF MAJOR CATEGORIES
                      INDUSTRIAL PROCESS, PRIMARY METALS                               PAGE  1
ANNUAL CHARGE RATES AND EMISSIONS PROJECTED TO 1982       RUN DATE= NOV 16,1977
 MODIFIED        TACRF                  EMISSIONS (MILLIONS OF TONS / YEAR)
   SCC        (SCC UNITS)       NOX           HC            CO             PART
303000000
                                .011          .198          5.718          .646

303001000      23618000.        NEG           NEG           NEG            .027
303002000       9456000.        NEG           NEG           NEG            .019
303003000     458400000.        .002          .184          .056           .024
303004000       1390000.        NEG           .006          .001           .042
303005000                       NEG           NEG           NEG            .312
303006000       4066000.        NEG           NEG           NEG            .022
303007000       2720000.        NEG           NEG           NEG            .001
```

MSCC	Source Category	Charge Rate Unit[a]
303000000	Primary Metals	N. A.
303001000	Aluminum reduction	Aluminum, tons/yr
303002000	Aluminum ore calcined	Tons/yr
303003000	Coke metallurgical	Coal, tons/yr
303004000	Coke beehive	Coal, tons/yr
303005000	Copper smelters	N. A.
303006000	Ferroalloy production (open furnace)	Tons/yr
303007000	Ferroalloy production (closed furnace)	

[a] N. A. (not applicable) is listed under "Charge Rate Unit" where the MSCC number is made up of two or more MSCCs whose charge rates are different.

Table 1-6-a. SUMMARY OF 1982 EMISSIONS AND CHARGE RATES (Continued)

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                              SUMMARY OF MAJOR CATEGORIES
                          INDUSTRIAL PROCESS, PRIMARY METALS                          PAGE  2
ANNUAL CHARGE RATES AND EMISSIONS PROJECTED TO 1982     RUN DATE= NOV 16,1977
 MODIFIED         TACRF
   SCC          (SCC UNITS)            EMISSIONS (MILLIONS OF TONS / YEAR)
                               NOX            HC            CO            PART
303008000                      NEG            NEG          4.008          .125
303009000       136670000.     .010           .008         1.651          .019
303010000         6970000.     .000           .000          NEG           .004
303011000                      NEG            NEG           NEG           .006
303012000           65000.     NEG            NEG          .000           NEG
303030000         1554000.     NEG            NEG           NEG           .001
303999000        36000000.     .002           .001         .002           .054
```

MSCC	Source Category	Charge Rate Unit[a]
303008000	Iron production	N. A.
303009000	Steel production	Tons/yr
303010000	Lead smelters	N. A.
303011000	Molybdenum	N. A.
303012000	Titanium	N. A.
303030000	Zinc smelting	Tons/yr
303999000	Miscellaneous metallurgical processes	Tons/yr

[a] N. A. (not applicable) is listed under "Charge Rate Unit" where the MSCC number is made up of two or more MSCCs whose charge rates are different.

Table 1-6-a. SUMMARY OF 1982 EMISSIONS AND CHARGE RATES (Continued)

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                          SUMMARY OF MAJOR CATEGORIES

                  INDUSTRIAL PROCESS, SECONDARY METALS                 PAGE  1

ANNUAL CHARGE RATES AND EMISSIONS PROJECTED TO 1982      RUN DATE= NOV 16,1977

 MODIFIED         TACRF                  EMISSIONS (MILLIONS OF TONS / YEAR)
   SCC         (SCC UNITS)          NOX            HC             CO            PART

304000000                          .030           .017           .379           .072

304001000        4222200.          .002           .003           NEG            .005
304002000         451900.          .000           .000           NEG            .000
304003000       6754200.           .000           .002           .365           .017
304004000         709440.          NEG            .000           NEG            .001
304006000          21830.          NEG            NEG            .000           NEG
304007000      174420000.          .025           .004           .010           .038
304008000         570400.          NEG            .004           NEG            .000
304009000        1040000.          NEG            NEG            .003           .000
304010000          18950.          NEG            NEG            .000           NEG
304020000         312350.          NEG            NEG            NEG            .000
304050000        1628400.          NEG            .001           NEG            .000
304999000       12580000.          .002           .002           NEG            .011
```

MSCC	Source Category	Charge Rate Unit
304000000	Secondary Metals	
304001000	Aluminum operations	Tons/yr
304002000	Brass/bronze melt	Tons/yr
304003000	Gray iron	Tons/yr
304004000	Secondary lead smelting	Tons/yr
304006000	Secondary magnesium	Tons/yr
304007000	Steel foundry	Tons/yr
304008000	Secondary zinc	Tons/yr
304009000	Malleable iron	Tons/yr
304010000	Nickel	Tons/yr
304020000	Furnace electrodes	Tons/yr
304050000	Miscellaneous casting and fabrication	Tons/yr
304999000	Miscellaneous secondary metal activity	Tons/yr

Table 1-6-a. SUMMARY OF 1982 EMISSIONS AND CHARGE RATES (Continued)

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                                   SUMMARY OF MAJOR CATEGORIES
                           INDUSTRIAL PROCESS, MINERAL PRODUCTS                         PAGE  1
ANNUAL CHARGE RATES AND EMISSIONS PROJECTED TO 1982      RUN DATE= NOV 16,1977
  MODIFIED        TACRF                      EMISSIONS (MILLIONS OF TONS / YEAR)
    SCC        (SCC UNITS)            NOX           HC            CO            PART

 305000000                           .306          .013          .050          6.397

 305002000                           .044          .001          .003           .500
 305003000                            NEG           NEG           NEG           .382
 305005000                            NEG           NEG           NEG           .002
 305006000                           .078           NEG           NEG           .433
 305007000                           .045           NEG           NEG           .272
 305008000                           .003           NEG          .001           .157
 305009000                            NEG           NEG           NEG           .014
 305010000                           .005           NEG          .000           .068
 305014000                           .020           NEG           NEG           .011
 305015000                           .002           NEG           NEG           .068
 305016000                           .004          .000          .002           .307
 305018000                            NEG           NEG           NEG           .001
 305020000                           .058          .002          .012          3.337
 305022000                            NEG           NEG           NEG           .040
 305024000                            NEG           NEG           NEG           .003
 305025000                           .031           NEG          .008           .604
 305999000                           .017          .009          .023           .187
```

MSCC	Source Category	Charge Rate Unit
305000000	Mineral Products	
305002000	Asphaltic concrete	Tons/yr
305003000	Brick manufacturing	Tons/yr
305005000	Castable refractory	Tons/yr
305006000	Cement manufacturing, dry	N. A.
305007000	Cement manufacturing, wet	N. A.
305008000	Ceramic/clay manufacturing	Tons/yr
305009000	Clay/fly ash sinter	Tons/yr
305010000	Coal cleaning	Tons/yr
305014000	Glass manufacturing	Tons/yr
305015000	Gypsum manufacturing	Tons/yr
305016000	Lime manufacturing	Tons/yr
305018000	Perlite manufacturing	Tons/yr
305020000	Stone quarry process	Tons/yr
305022000	Potash production	Tons/yr
305024000	Magnesium carbinate	Tons/yr
305025000	Sand and gravel processing	Tons/yr
305999000	Miscellaneous mineral products	N. A.

Table 1-6-a. SUMMARY OF 1982 EMISSIONS AND CHARGE RATES (Continued)

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                               SUMMARY OF MAJOR CATEGORIES
                        INDUSTRIAL PROCESS, PETROLEUM PRODUCTS                       PAGE  1
  ANNUAL CHARGE RATES AND EMISSIONS PROJECTED TO 1982     RUN DATE= NOV 16,1977
   MODIFIED           TACRF                  EMISSIONS (MILLIONS OF TONS / YEAR)
     SCC           (SCC UNITS)          NOX             HC              CO              PART
  306000000
                                        .312            .471           8.365            .209
  306001000
  306002000          1766000.           .253            .060            .039            .077
  306003000            54600.           .059            .183           9.826            .102
  306008000         31290000.            NEG            .002            .100             NEG
  306012000           124000.            NEG            .226             NEG             NEG
                                         NEG             NEG             NEG            .030
```

MSCC	Source Category	Charge Rate Unit [a]
306000000	Petroleum Industry	
306001000	Process heater	N.A.
306002000	Fluid catalytic crackers	1000 bbl/yr
306003000	Moving bed catalytic crackers	1000 bbl/yr
306008000	Miscellaneous leakage	1000 bbl capacity/yr
306012000	Fluid coking	1000 bbl feed/yr

[a] N.A. (not applicable) is listed under "Charge Rate Unit" where the MSCC number is made up of two or more MSCCs whose charge rates are different.

Table 1-6-a. SUMMARY OF 1982 EMISSIONS AND CHARGE RATES (Continued)

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                         SUMMARY OF MAJOR CATEGORIES

                      INDUSTRIAL PROCESS, WOOD PRODUCTS                      PAGE   1

ANNUAL CHARGE RATES AND EMISSIONS PROJECTED TO 1982     RUN DATE= NOV 16,1977

 MODIFIED          TACRF                 EMISSIONS (MILLIONS OF TONS / YEAR)
   SCC          (SCC UNITS)         NOX            HC             CO             PART

307000000                           .002           .017           .398           .339

307001000                           NEG            NEG            .375           .285
307002000                           .000           NEG            .021           .096
307004000        13297000.          NEG            .007           NEG            .001
307006000          392000.          NEG            .001           NEG            NEG
307007000        70520000.          .002           .004           .001           .023
307008000       162400000.          NEG            .001           .001           .021
307020000         2650000.          NEG            .004           NEG            .004
307999000               0.         0.000          0.000          0.000          0.000
```

MSCC	Source Category	Charge Rate Unit
307000000	Wood Products	
307001000	Sulfate pulping	Tons/yr, air dried
307002000	Sulfite pulping	Tons/yr, air dried
307004000	Pulpboard mfg.	Tons/yr
307006000	Tall oil/rosin	Tons/yr
307007000	Plywood/particle board	Tons/yr
307008000	Sawmill operations	Tons/yr
307020000	Furniture manufacturing	Tons/yr
307999000	Miscellaneous wood products	Tons/yr

Table 1-6-a. SUMMARY OF 1982 EMISSIONS AND CHARGE RATES (Continued)

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                                   SUMMARY OF MAJOR CATEGORIES
                                     HYDROCARBON EVAPORATION                             PAGE   1
ANNUAL CHARGE RATES AND EMISSIONS PROJECTED TO 1982      RUN DATE= NOV 16,1977
  MODIFIED          TACRF                      EMISSIONS (MILLIONS OF TONS / YEAR)
    SCC         (SCC UNITS)          NOX              HC               CO              PART
400000000
                                     NEG            2.258             NEG              .012
401000000
                                     NEG             .106             NEG              NEG
401001000           43230.           NEG             .001             NEG              NEG
401002000          114600.           NEG             .094             NEG              NEG
401999000          133700.           NEG             .011             NEG              NEG
```

MSCC	Source Category	Charge Rate Unit[a]
400000000	Point Source Evaporation	N. A.
401000000	Cleaning Solvents	N. A.
401001000	Dry cleaning	Clothes, tons/yr
401002000	Degreasing	Solvent, tons/yr
401999000	Miscellaneous solvent use	Solvent, tons/yr

[a] N. A. (not applicable) is listed under "Charge Rate Unit" where the MSCC number is made up of two or more MSCCs whose charge rates are different.

Table 1-6-a. SUMMARY OF 1982 EMISSIONS AND CHARGE RATES (Continued)

```
                              SUMMARY OF MAJOR CATEGORIES
                               HYDROCARBON EVAPORATION                              PAGE  2
ANNUAL CHARGE RATES AND EMISSIONS PROJECTED TO 1982     RUN DATE= NOV 16,1977
 MODIFIED        TACRF                   EMISSIONS (MILLIONS OF TONS / YEAR)
   SCC        (SCC UNITS)          NOX            HC             CO              PART
402000000      12516000.            NEG          1.330          NEG              .012

402001000        634340.            NEG           .118          NEG              NEG
402002000       5944200.            NEG           .259          NEG              NEG
402003000        427530.            NEG           .113          NEG              NEG
402004000        102440.            NEG           .030          NEG              NEG
402005000        399150.            NEG           .092          NEG              NEG
402006000       1378300.            NEG           .293          NEG              NEG
402007000       1666500.            NEG           .241          NEG              NEG
402008000        231000.            NEG           .056          NEG              NEG
402999000       1732200.            NEG           .129          NEG              .012
```

MSCC	Source Category	Charge Rate Unit
402000000	Surface Coating	Coating, tons/yr
402001000	Paint	Coating, tons/yr
402002000	Paper coatings	Coating, tons/yr
402003000	Varnish and shellac	Coating, tons/yr
402004000	Lacquer	Coating, tons/yr
402005000	Enamel	Coating, tons/yr
402006000	Primer	Coating, tons/yr
402007000	Fabric coatings	Coating, tons/yr
402008000	Oven coatings	Coating, tons/yr
402999000	Miscellaneous coatings	Coating, tons/yr

Table 1-6-a. SUMMARY OF 1982 EMISSIONS AND CHARGE RATES (Continued)

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                               SUMMARY OF MAJOR CATEGORIES
                                 HYDROCARBON EVAPORATION                            PAGE  3
ANNUAL CHARGE RATES AND EMISSIONS PROJECTED TO 1982     RUN DATE= NOV 16,1977
 MODIFIED          IACRE                    EMISSIONS (MILLIONS OF TONS / YEAR)
   SCC          (SCC UNITS)          NOX               HC              CO              PART
403000000                            NEG              .326            NEG              NEG

403001000                            NEG              .082            NEG              NEG
403002000                            NEG              .217            NEG              NEG
403003000        35860000.           NEG              .157            NEG              NEG
403999000        15000000.           NEG              .069            NEG              NEG

406000000       196220000.           NEG              .296            NEG              NEG

406001000        83616000.           NEG              .057            NEG              NEG
406002000       112600000            NEG              .239            NEG              NEG
```

MSCC	Source Category	Charge Rate Unit[a]
403000000	Petroleum Storage	N. A
403001000	Fixed roof	N. A.
403002000	Floating roof	N. A.
403003000	Variable vapor space	1000 gal/yr
403999000	Miscellaneous storage	1000 gal/yr
406000000	Petroleum Marketing & Transportation	1000 gal/yr
406001000	Rail and truck transportation	1000 gal/yr
406002000	Marine vessel transportation	1000 gal/yr

[a] N. A (not applicable) is listed under "Charge Rate Unit" where the MSCC number is made up of two or more MSCCs whose charge rates are different.

Table 1-6-b. SUMMARY OF 1982 EMISSIONS AND CHARGE RATES UNCERTAINTY

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                                SUMMARY OF MAJOR CATEGORIES
                          EXTERNAL COMBUSTION, BOILER CATEGORY                    PAGE  1
TACR AND EMISSION UNCERTAINTIES PROJECTED TO 1982          RUN DATE= NOV 16,1977
 MODIFIED          TACRP                    EMISSIONS (MILLIONS OF TONS / YEAR)
   SCC          (SCC UNITS)            NOX              HC               CO              PART
100000000                           + 1.021          + .136           + .113          + 1.089
                                    -  .969          - .034           - .078          - 1.094

101000000                           +  .951          + .133           + .099          + 1.016
                                    -  .927          - .024           - .066          - 1.014

101002000      +   25840000.        +  .926          + .132           + .094          + 1.013
               -   25587000.        -  .926          - .019           - .062          - 1.012
101004000      +   17150000.        +  .213          + .021           + .032          +  .069
               -   12302000.        -  .045          - .015           - .022          -  .049
101005000      +          0.        + 0.000          + 0.000          + 0.000         + 0.000
               -          0.        - 0.000          - 0.000          - 0.000         - 0.000
101006000      +     410340.        +  .030          + .000           + .006          +  .003
               -     322310.        -  .008          - .000           - .004          -  .002
101007000      +      15220.        +  .000             NEG              NEG              NEG
               -      15220.        -  .000             NEG              NEG              NEG
```

MSCC	Source Category	Charge Rate Unit
100000000	External Combustion (Boiler)	
101000000	Electric Generation	
101002000	Bituminous coal	Tons burned/yr
101004000	Residual oil	1000 gal/yr
101005000	Distillate oil	1000 gal/yr
101006000	Natural gas	Million cu ft/yr
101007000	Process gas	Million cu ft/yr

Table 1-6-b. SUMMARY OF 1982 EMISSIONS AND CHARGE RATES UNCERTAINTY (Continued)

```
                                    SUMMARY OF MAJOR CATEGORIES
                              EXTERNAL COMBUSTION, BOILER CATEGORY                     PAGE  2
TACF AND EMISSION UNCERTAINTIES PROJECTED TO 1982              RUN DATE= NOV 16,1977
 MODIFIED          TACRF                   EMISSIONS (MILLIONS OF TONS / YEAR)
   SCC          (SCC UNITS)           NOX              HC              CO              PART
102000000                           + .372          + .027          + .054          + .392
                                    - .291          - .024          - .041          - .412

102002000     +   14393000.         + .262          + .021          + .045          + .391
              -   14393000.         - .261          - .021          - .034          - .411
102004000     +    2416600.         + .200          + .015          + .019          + .023
              -    2416600.         - .079          - .010          - .017          - .028
102005000     +     683580.         + .073          + .006          + .007          + .005
              -     683580.         - .002          - .004          - .005          - .005
102006000     +     462800.         + .156          + .004          + .022          + .004
              -     462800.         - .103          - .003          - .015          - .004
102007000     +     142990.         + .000            NEG             NEG             NEG
              -     142990.         - .000            NEG             NEG             NEG
```

MSCC	Source Category	Charge Rate Unit
102000000	Industrial	
102002000	Bituminous coal	Tons burned/yr
102004000	Residual oil	1000 gal/yr
102005000	Distillate oil	1000 gal/yr
102006000	Natural gas	Million cu ft/yr
102007000	Process gas	Million cu ft/yr

Table 1-6-b. SUMMARY OF 1982 EMISSIONS AND CHARGE RATES UNCERTAINTY (Continued)

```
                                SUMMARY OF MAJOR CATEGORIES
                                INTERNAL COMBUSTION ENGINES                               PAGE  1
TACR AND EMISSION UNCERTAINTIES PROJECTED TO 1982          RUN DATE= NOV 16,1977
 MODIFIED          TACRF               EMISSIONS (MILLIONS OF TONS / YEAR)
   SCC          (SCC UNITS)        NOX            HC             CO            PART
 200000000
                                 + .433        + .297         + .042         + .027
                                 - .193        - .140         - .019         - .010
 201000000
                                 + .405        + .033         + .032         + .026
                                 - .151        - .032         - .012         - .010

 201001000    +    3570500.      + .398        + .005         + .031         + .026
              -    1350600.      - .149        - .002         - .012         - .010
 201002000    +     420910.      + .074        + .002         + .003         + .001
              -     107630.      - .025        - .000         - .000         - .000
 201003000    +      20738.      + .003        + .000         + .002         + .001
              -      20738.      - .003        - .000         - .001         - .001
 201999000                       + .006        + .032         + .001         + .002
                                 - .006        - .032         - .001         - .002
```

MSCC	Source Category	Charge Rate Unit
200000000	Internal Combustion	
201000000	Electric Generation	
201001000	Distillate oil	1000 gal/yr
201002000	Natural gas	Million cu ft/yr
201003000	Diesel	1000 gal/yr
201999000	Miscellaneous fuel	N.A.[a]

[a] N.A. (not applicable) is listed under "Charge Rate Unit" where the MSCC number is made up of two or more MSCCs whose charge rates are different.

Table 1-6-b. SUMMARY OF 1982 EMISSIONS AND CHARGE RATES UNCERTAINTY (Continued)

```
                              SUMMARY OF MAJOR CATEGORIES
                              INTERNAL COMBUSTION ENGINES                          PAGE  2
TACR AND EMISSION UNCERTAINTIES PROJECTED TO 1982       RUN DATE= NOV 16.1977
 MODIFIED          TACRP                   EMISSIONS (MILLIONS OF TONS / YEAR)
   SCC          (SCC UNITS)         NOX              HC               CO               PART
202000000
                                  +  .153         +  .295          +  .028          +  .005
                                  -  .120         -  .136          -  .015          -  .003

202001000      +      60420.      +  .003         +  .000          +  .001          +  .001
               -      60420.      -  .003         -  .000          -  .001          -  .001
202002000      +     687510.      +  .153         +  .040          +  .027          +  .005
               -     322670.      -  .119         -  .130          -  .015          -  .003
202003000      +       2769.      +  .000         +  .000          +  .004          +  .000
               -       2769.      -  .000         -  .000          -  .002          -  .000
202004000      +      26695.      +  .005         +  .000          +  .002          +  .000
               -      26695.      -  .005         -  .000          -  .002          -  .000
202999000      +      18461.      +  .003         +  .292          +  .001          +  .000
               -      18461.      -  .003         -  .133          -  .001          -  .000
```

MSCC	Source Category	Charge Rate Unit
202000000	Industrial IC Engines	
202001000	Distillate oil turbine	1000 gal/yr
202002000	Distillate oil reciprocating	1000 gal/yr
202003000	Natural gas turbine	Million cu ft/yr
202004000	Natural gas reciprocating	Million cu ft/yr
202999000	Miscellaneous fuels[a]	Million cu ft/yr

[a] Although this category is made up of two MSCCs whose units are different, only one (202999970) was studied.

Table 1-6-b. SUMMARY OF 1982 EMISSIONS AND CHARGE RATES UNCERTAINTY (Continued)

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                         SUMMARY OF MAJOR CATEGORIES
                 INDUSTRIAL PROCESS, CHEMICAL MANUFACTURING             PAGE  1
TACR AND EMISSION UNCERTAINTIES PROJECTED TO 1982       RUN DATE= NOV 16,1977
 MODIFIED          TACRF                  EMISSIONS (MILLIONS OF TONS / YEAR)
   SCC          (SCC UNITS)          NOX             HC             CO               PART
301000000
                                     NEG        +  .124       +  .487               NEG
                                     NEG        -  .115       -  .440               NEG

301002000   +       335720.          NEG        +  .035       +  .001               NEG
            -       335720.          NEG        -  .035       -  .001               NEG
301003000   +        79980.          NEG        +  .005       +  .038               NEG
            -        79980.          NEG        -  .005       -  .038               NEG
301005000   +       247220.          NEG        +  .099       +  .469               NEG
            -       241630.          NEG        -  .088       -  .416               NEG
301999000   +     17464000.          NEG        +  .065       +  .129               NEG
            -     17464000.          NEG        -  .065       -  .129               NEG
```

MSCC	Source Category	Charge Rate Unit
300000000	Industrial Processes	
301000000	Chemical Manufacturing	
301002000	Ammonia production with methanator	Tons/yr
301003000	Ammonia production with CO absorber	Tons/yr
301005000	Carbon black production	Tons/yr
301999000	Miscellaneous chemical manufacturing	Tons/yr

Table 1-6-b. SUMMARY OF 1982 EMISSIONS AND CHARGE RATES UNCERTAINTY (Continued)

```
                         SUMMARY OF MAJOR CATEGORIES
                    INDUSTRIAL PROCESS, PRIMARY METALS                     PAGE  1
TACR AND EMISSION UNCERTAINTIES PROJECTED TO 1982        RUN DATE= NOV 16,1977
 MODIFIED          TACRF            EMISSIONS (MILLIONS OF TONS / YEAR)
   SCC          (SCC UNITS)        NOX           HC            CO            PART
303000000
                                + .004        + .049        + 4.217       + .131
                                - .010        - .120        - 2.019       - .118
303001000    +     9010200.        NEG           NEG           NEG        + .072
             -     4307300.        NEG           NEG           NEG        - .016
30300[illegible]000    +      799700.        NEG           NEG           NEG        + .008
             -      799700.        NEG           NEG           NEG        - .009
303003000    +    77846000.     + .001        + .048        + .014        + .003
             -    77846000.     - .001        - .120        - .035        - .009
303004000    +      166480.        NEG        + .001        + .000        + .042
             -      166480.        NEG        - .004        - .000        - .042
303005000                          NEG           NEG           NEG        + .084
                                   NEG           NEG           NEG        - .034
303006000    +     1737000.        NEG           NEG           NEG        + .020
             -     1704500.        NEG           NEG           NEG        - .013
303007000    +     1032700.        NEG           NEG           NEG        + .001
             -     1032700.        NEG           NEG           NEG        - .001
```

MSCC	Source Category	Charge Rate Unit[a]
303000000	Primary Metals	
303001000	Aluminum reduction	Aluminum, tons/yr
303002000	Aluminum ore calcined	Tons/yr
303003000	Coke metallurgical	Coal, tons/yr
303004000	Coke beehive	Coal, tons/yr
303005000	Copper smelters	N. A.
303006000	Ferroalloy production (open furnace)	Tons/yr
303007000	Ferroalloy production (closed furnace)	

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[a] N. A. (not applicable) is listed under "Charge Rate Unit" where the MSCC number is made up of two or more MSCCs whose charge rates are different.

Table 1-6-b. SUMMARY OF 1982 EMISSIONS AND CHARGE RATES UNCERTAINTY (Continued)

```
                               SUMMARY OF MAJOR CATEGORIES
                           INDUSTRIAL PROCESS, PRIMARY METALS                         PAGE  2
 TACF AND EMISSION UNCERTAINTIES PROJECTED TO 1982            RUN DATE= NOV 16,1977
  MODIFIED          TACRF                 EMISSIONS (MILLIONS OF TONS / YEAR)
    SCC          (SCC UNITS)         NOX              HC              CO            PART
 303008000                           NEG              NEG         + 2.765        +  .047
                                     NEG              NEG         - 1.519        -  .063
 303009000    +   22515000.     +   .004        +    .003         + 3.184        +  .010
              -   22515000.     -   .010        -    .008         - 1.329        -  .016
 303010000    +    1769700.     +   .000        +    .000            NEG         +  .003
              -    1769700.     -   .000        -    .000            NEG         -  .003
 303011000                           NEG              NEG            NEG         +  .003
                                     NEG              NEG            NEG         -  .003
 303012000    +      20880.          NEG              NEG         +  .003           NEG
              -      20880.          NEG              NEG         -  .000           NEG
 303030000    +     372780.          NEG              NEG            NEG         +  .001
              -     372780.          NEG              NEG            NEG         -  .001
 303999000    +    8544000.     +   .000        +    .000         +  .000        +  .014
                   8544000.     -   .002        -    .001         -  .002        -  .014
```

MSCC	Source Category	Charge Rate Unit[a]
303008000	Iron production	N. A.
303009000	Steel production	Tons/yr
303010000	Lead smelters	N. A.
303011000	Molybdenum	N. A.
303012000	Titanium	N. A.
303030000	Zinc smelting	Tons/yr
303999000	Miscellaneous metallurgical processes	Tons/yr

[a] N. A. (not applicable) is listed under "Charge Rate Unit" where the MSCC number is made up of two or more MSCCs whose charge rates are different.

Table 1-6-b. SUMMARY OF 1982 EMISSIONS AND CHARGE RATES UNCERTAINTY (Continued)

```
                                 SUMMARY OF MAJOR CATEGORIES
                          INDUSTRIAL PROCESS, SECONDARY METALS                    PAGE  1a
TACP AND EMISSION UNCERTAINTIES PROJECTED TO 1982        RUN DATE= NOV 16,1977
 MODIFIED        TACRF                    EMISSIONS (MILLIONS OF TONS / YEAR)
   SCC        (SCC UNITS)          NOX            HC             CO            PART
304000000
                                 + .004        + .002        + .340        + .026
                                 - .014        - .005        - .340        - .030

304001000   +     321100.        + .000        + .000          NEG         + .003
            -     321100.        - .001        - .001          NEG         - .001
304002000   +      79617.        + .000        + .000          NEG         + .000
            -      79617.        - .000        - .000          NEG         - .000
304003000   +   11808000.        + .000        + .001        + .340        + .011
            -   11808000.        - .000        - .002        - .340        - .013
304004000   +      54591.          NEG         + .000          NEG         + .000
            -      54591.          NEG         - .000          NEG         - .000
304006000   +       5096.          NEG           NEG         + .001          NEG
            -       5096.          NEG           NEG         - .000          NEG
304007000   +   10779000.        + .004        + .001        + .020        + .023
            -   10779000.        - .014        - .004        - .001        - .027
304008000   +     133490.          NEG         + .001          NEG         + .000
            -     133490.          NEG         - .003          NEG         - .000
304009000   +     287310.          NEG           NEG         + .010        + .000
            -     287310.          NEG           NEG         - .002        - .000
```

MSCC	Source Category	Charge Rate Unit[a]
304000000	Secondary Metals	
304001000	Aluminum operations	Tons/yr
304002000	Brass/bronze melt	Tons/yr
304003000	Gray iron	Tons/yr
304004000	Secondary lead smelting	Tons/yr
304006000	Secondary magnesium	Tons/yr
304007000	Steel foundry	Tons/yr
304008000	Secondary zinc	Tons/yr
304009000	Malleable iron	Tons/yr

Table 1-6-b. SUMMARY OF 1982 EMISSIONS AND CHARGE RATES UNCERTAINTY (Continued)

```
                                SUMMARY OF MAJOR CATEGORIES
                          INDUSTRIAL PROCESS, SECONDARY METALS                      PAGE  1b
     TACR AND EMISSION UNCERTAINTIES PROJECTED TO 1982         RUN DATE= NOV 16,1977
   MODIFIED           TACRF                      EMISSIONS (MILLIONS OF TONS / YEAR)
     SCC          (SCC UNITS)          NOX            HC             CO              PART
   304010000   +       7988.           NEG            NEG        +  .002              NEG
               -       7988.           NEG            NEG        -  .000              NEG
   304020000   +      83200.           NEG            NEG            NEG          +  .000
               -      83200.           NEG            NEG            NEG          -  .000
   304050000   +     491050.           NEG        +  .000            NEG          +  .000
               -     491050.           NEG        -  .001            NEG          -  .000
   304999000   +    3370800.       +  .001        +  .001            NEG          +  .007
               -    3370800.       -  .002        -  .002            NEG          -  .004
```

MSCC	Source Category	Charge Rate Unit[a]
304010000	Nickel	Tons/yr
304020000	Furnace electrodes	Tons/yr
304050000	Misc. casting & fabrication	Tons/yr
304999000	Misc. secondary metal activity	Tons/yr

Table 1-6-b. SUMMARY OF 1982 EMISSIONS AND CHARGE RATES UNCERTAINTY (Continued)

```
                              SUMMARY OF MAJOR CATEGORIES

                        INDUSTRIAL PROCESS, MINERAL PRODUCTS                        PAGE  1

  TACP AND EMISSION UNCERTAINTIES PROJECTED TO 1982        RUN DATE= NOV 16,1977

  MODIFIED         TACRP                       EMISSIONS (MILLIONS OF TONS / YEAR)
    SCC         (SCC UNITS)            NOX              HC              CO            PART

  305000000                         +  .050         +  .004         +  .010         + 1.041
                                    -  .023         -  .004         -  .008         - 1.142

  305002000                         +  .011         +  .000         +  .001         +  .359
                                    -  .011         -  .000         -  .000         -  .404
  305003000                            NEG             NEG             NEG          +  .116
                                       NEG             NEG             NEG          -  .145
  305005000                            NEG             NEG             NEG          +  .001
                                       NEG             NEG             NEG          -  .001
  305006000                         +  .012            NEG             NEG          +  .322
                                    -  .012            NEG             NEG          -  .330
  305007000                         +  .010            NEG             NEG          +  .230
                                    -  .007            NEG             NEG          -  .236
  305008000                         +  .000            NEG          +  .000         +  .048
                                    -  .000            NEG          -  .000         -  .061
  305009000                            NEG             NEG             NEG          +  .005
                                       NEG             NEG             NEG          -  .005
  305010000                         +  .001            NEG          +  .000         +  .023
                                    -  .001            NEG          -  .000         -  .041
```

MSCC	Source Category	Charge Rate Unit[a]
305000000	Mineral Products	
305002000	Asphaltic concrete	Tons/yr
305003000	Brick manufacturing	Tons/yr
305005000	Castable refractory	Tons/yr
305006000	Cement mfg., dry	N. A.
305007000	Cement mfg., wet	N. A.
305008000	Ceramic/clay mfg.	Tons/yr
305009000	Clay/fly ash sinter	Tons/yr
305010000	Coal cleaning	Tons/yr

[a] N.A. (not applicable) is listed under "Charge Rate Unit" where the MSCC number is made up of two or more MSCCs whose charge rates are different.

Table 1-6-b. SUMMARY OF 1982 EMISSIONS AND CHARGE RATES UNCERTAINTY (Continued)

```
                              SUMMARY OF MAJOR CATEGORIES

                      INDUSTRIAL PROCESS, MINERAL PRODUCTS                  PAGE  2
TACR AND EMISSION UNCERTAINTIES PROJECTED TO 1982       RUN DATE= NOV 16,1977
 MODIFIED          TACRF                 EMISSIONS (MILLIONS OF TONS / YEAR)
   SCC         (SCC UNITS)          NOX              HC              CO            PART
305014000                       +  .006             NEG             NEG         +  .003
                                -  .006             NEG             NEG         -  .003
305015000                       +  .042             NEG             NEG         +  .041
                                -  .000             NEG             NEG         -  .050
305016000                       +  .001        +  .000         +  .001          +  .237
                                -  .000        -  .000         -  .001          -  .285
305018000                          NEG              NEG             NEG         +  .001
                                   NEG              NEG             NEG         -  .001
305020000                       +  .014        +  .001         +  .007          +  .828
                                -  .010        -  .001         -  .004          -  .910
305022000                          NEG              NEG             NEG         +  .018
                                   NEG              NEG             NEG         -  .020
305024000                          NEG              NEG             NEG         +  .002
                                   NEG              NEG             NEG         -  .002
305025000                       +  .009             NEG        +  .003          +  .179
                                -  .009             NEG        -  .002          -  .179
305999000                       +  .007        +  .004         +  .007          +  .072
                                -  .005        -  .004         -  .007          -  .072
```

MSCC	Source Category	Charge Rate Unit [a]
305014000	Glass mfg.	Tons/yr
305015000	Gypsum mfg.	Tons/yr
305016000	Lime mfg.	Tons/yr
305018000	Perlite mfg.	Tons/yr
305020000	Stone quarry process	Tons/yr
305022000	Potash production	Tons/yr
305024000	Magnesium carbinate	Tons/yr
305025000	Sand & gravel processing	Tons/yr
305999000	Miscellaneous mineral products	N. A

[a] N. A. (not applicable) is listed under "Charge Rate Unit" where the MSCC number is made up of two or more MSCCs whose charge rates are different.

Table 1-6-b. SUMMARY OF 1982 EMISSIONS AND CHARGE RATES UNCERTAINTY (Continued)

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                                  SUMMARY OF MAJOR CATEGORIES
                           INDUSTRIAL PROCESS, PETROLEUM PRODUCTS                              PAGE  1
TACR AND EMISSION UNCERTAINTIES PROJECTED TO 1982           RUN DATE= NOV 16,1977
 MODIFIED        TACRF                    EMISSIONS (MILLIONS OF TONS / YEAR)
   SCC        (SCC UNITS)          NOX            HC              CO             PART
306000000
                               +  .035       +  .052        + 7.022        +  .017
                               -  .035       -  .052        - 7.022        -  .017
306001000
                               +  .034       +  .007        +  .007        +  .008
                               -  .034       -  .008        -  .007        -  .008
306002000    +     234740.     +  .008       +  .026        + 7.021        +  .015
             -     234740.     -  .008       -  .026        - 7.021        -  .015
306003000    +      29326.        NEG        +  .001        +  .054           NEG
             -      29326.        NEG        -  .001        -  .054           NEG
306008000    +    1911600.        NEG        +  .044           NEG            NEG
             -    1911600.        NEG        -  .044           NEG            NEG
306012000    +      16658.        NEG           NEG            NEG         +  .005
             -      16658.        NEG           NEG            NEG         -  .005
```

MSCC	Source Category	Charge Rate Unit
306000000	Petroleum Industry	
306001000	Process heater	N.A.[a]
306002000	Fluid catalytic crackers	1000 bbl/yr
306003000	Moving bed catalytic crackers	1000 bbl/yr
306008000	Miscellaneous leakage	1000 bbl capacity/yr
306012000	Fluid coking	1000 bbl feed/yr

[a] N.A. (not applicable) is listed under "Charge Rate Unit" where the MSCC number is made up of two or more MSCCs whose charge rates are different.

Table 1-6-b. SUMMARY OF 1982 EMISSIONS AND CHARGE RATES UNCERTAINTY (Continued)

```
                                SUMMARY OF MAJOR CATEGORIES
                             INDUSTRIAL PROCESS, WOOD PRODUCTS                    PAGE   1
TACR AND EMISSION UNCERTAINTIES PROJECTED TO 1982       RUN DATE= NOV 16,1977
  MODIFIED         TACRP                    EMISSIONS (MILLIONS OF TONS / YEAR)
    SCC        (SCC UNITS)           NOX            HC             CO             PART
307000000                          +  .000       +  .001       +  .468       +  .170
                                   -  .000       -  .001       -  .287       -  .203

307001000                             NEG           NEG        +  .468       +  .170
                                      NEG           NEG        -  .287       -  .202
307002000                          +  .000          NEG        +  .005       +  .001
                                   -  .000          NEG        -  .005       -  .001
307004000    +     387260.            NEG        +  .000          NEG        +  .000
             -     387260.            NEG        -  .000          NEG        -  .000
307006000    +      50249.            NEG        +  .000          NEG           NEG
             -      50249.            NEG        -  .000          NEG           NEG
307007000    +     340480.         +  .000       +  .000       +  .000       +  .004
             -     340480.         -  .000       -  .000       -  .000       -  .004
307008000    +          0.            NEG        + 0.000       + 0.000       + 0.000
             -          0.            NEG        - 0.000       - 0.000       -  .017
307020000    +     200000.            NEG        +  .000          NEG        +  .000
             -     200000.            NEG        -  .000          NEG        -  .000
307999000    +          0.         + 0.000       + 0.000       + 0.000       + 0.000
             -          0.         - 0.000       - 0.000       - 0.000       - 0.000
```

MSCC	Source Category	Charge Rate Unit
307000000	Wood Products	
307001000	Sulfate pulping	Tons/yr, air dried
307002000	Sulfite pulping	Tons/yr, air dried
307004000	Pulpboard mfg.	Tons/yr
307006000	Tall oil/rosin	Tons/yr
307007000	Plywood/particle board	Tons/yr
307008000	Sawmill operations	Tons/yr
307020000	Furniture manufacturing	Tons/yr
307999000	Miscellaneous wood products	Tons/yr

Table 1-6-b. SUMMARY OF 1982 EMISSIONS AND CHARGE RATES UNCERTAINTY (Continued)

```
                              SUMMARY OF MAJOR CATEGORIES

                               HYDROCARBON EVAPORATION                              PAGE  1

TACP AND EMISSION UNCERTAINTIES PROJECTED TO 1982        RUN DATE= NOV 15,1977

 MODIFIED          TACPF                   EMISSIONS (MILLIONS OF TONS / YEAR)
   SCC          (SCC UNITS)          NOX             HC             CO             PART

400000000                             NEG       +  .683             NEG       +   .003
                                      NEG       -  .436             NEG       -   .003

401000000                             NEG       +  .104             NEG            NEG
                                      NEG       -  .088             NEG            NEG

401001000     +      35891.           NEG       +  .006             NEG            NEG
              -      22099.           NEG       -  .000             NEG            NEG
401002000     +     110720.           NEG       +  .102             NEG            NEG
              -      97660.           NEG       -  .088             NEG            NEG
401999000     +      34875.           NEG       +  .018             NEG            NEG
              -      34875.           NEG       -  .011             NEG            NEG
```

MSCC	Source Category	Charge Rate Unit[a]
400000000	Point Source Evaporation	N. A.
401000000	Cleaning Solvents	N. A.
401001000	Dry cleaning	Clothes, tons/yr
401002000	Degreasing	Solvent, tons/yr
401999000	Miscellaneous solvent use	Solvent, tons/yr

[a] N. A. (not applicable) is listed under "Charge Rate Unit" where the MSCC number is made up of two or more MSCCs whose charge rates are different.

Table 1-6-b. SUMMARY OF 1982 EMISSIONS AND CHARGE RATES UNCERTAINTY (Continued)

```
                         SUMMARY OF MAJOR CATEGORIES

                          HYDROCARBON EVAPORATION                     PAGE  2
 TACR AND EMISSION UNCERTAINTIES PROJECTED TO 1982        RUN DATE= NOV 16,1977
 MODIFIED          TACRP                EMISSIONS (MILLIONS OF TONS / YEAR)
   SCC          (SCC UNITS)         NOX            HC          CO            PART
402000000    +      7562400.        NEG      +   .618         NEG        +   .003
             -      5501600.        NEG      -   .361         NEG        -   .003

402001000    +        84614.        NEG      +   .174         NEG              NEG
             -        84614.        NEG      -   .084         NEG              NEG
402002000    +      7563000.        NEG      +   .277         NEG              NEG
             -      5474600.        NEG      -   .131         NEG              NEG
402003000    +        56378.        NEG      +   .165         NEG              NEG
             -        56378.        NEG      -   .085         NEG              NEG
402004000    +        26144.        NEG      +   .033         NEG              NEG
             -        26144.        NEG      -   .017         NEG              NEG
402005000    +       104260.        NEG      +   .098         NEG              NEG
             -       104260.        NEG      -   .053         NEG              NEG
402006000    +       183970.        NEG      +   .453         NEG              NEG
             -       183970.        NEG      -   .218         NEG              NEG
402007000    +       107080.        NEG      +   .125         NEG              NEG
             -       107080.        NEG      -   .186         NEG              NEG
402008000    +        65220.        NEG      +   .062         NEG              NEG
             -        65220.        NEG      -   .034         NEG              NEG
402999000    +       470300.        NEG      +   .112         NEG        +   .003
             -       470300.        NEG      -   .112         NEG        -   .003
```

MSCC	Source Category	Charge Rate Unit
402000000	Surface Coating	Coating, tons/yr
402001000	Paint	Coating, tons/yr
402002000	Paper coatings	Coating, tons/yr
402003000	Varnish and shellac	Coating, tons/yr
402004000	Lacquer	Coating, tons/yr
402005000	Enamel	Coating, tons/yr
402006000	Primer	Coating, tons/yr
402007000	Fabric coatings	Coating, tons/yr
402008000	Oven coatings	Coating, tons/yr
402999000	Miscellaneous coatings	Coating, tons/yr

Table 1-6-b. SUMMARY OF 1982 EMISSIONS AND CHARGE RATES UNCERTAINTY (Continued)

```
                         SUMMARY OF MAJOR CATEGORIES
                          HYDROCARBON EVAPORATION                              PAGE  3
TACR AND EMISSION UNCERTAINTIES PROJECTED TO 1982          RUN DATE= NOV 16,1977
 MODIFIED           TACR                    EMISSIONS (MILLIONS OF TONS / YEAR)
   SCC          (SCC UNITS)          NOX              HC             CO             PART
403000000
                                     NEG        +   .179            NEG            NEG
                                     NEG        -   .189            NEG            NEG
403001000
                                     NEG        +   .017            NEG            NEG
403002000                            NEG        -   .035            NEG            NEG
                                     NEG        +   .149            NEG            NEG
403003000     +      904490.         NEG        -   .140            NEG            NEG
              -      904490.         NEG        +   .027            NEG            NEG
403999000     +    20100000.         NEG        -   .101            NEG            NEG
              -    15000000.         NEG        +   .093            NEG            NEG
                                     NEG        -   .069            NEG            NEG
```

MSCC	Source Category	Charge Rate Unit[a]
403000000	Petroleum Storage	N. A.
403001000	Fixed roof	N. A.
403002000	Floating roof	N. A.
403003000	Variable vapor space	1000 gal/yr
403999000	Miscellaneous storage	1000 gal/yr

[a] N. A. (not applicable) is listed under "Charge Rate Unit" where the MSCC number is made up of two or more MSCCs whose charge rates are different.

Table 1-6-b. SUMMARY OF 1982 EMISSIONS AND CHARGE RATES UNCERTAINTY (Continued)

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                         SUMMARY OF MAJOR CATEGORIES
                           HYDROCARBON EVAPORATION                         PAGE  4
TACR AND EMISSION UNCERTAINTIES PROJECTED TO 1982        RUN DATE= NOV 16,1977
 MODIFIED         TACRF                     EMISSIONS (MILLIONS OF TONS / YEAR)
   SCC         (SCC UNITS)          NOX             HC            CO          PART
406000000   +   45022000.           NEG       +   .205           NEG          NEG
            -   19085000.           NEG       -   .128           NEG          NEG

406001000   +   17757000.           NEG       +   .170           NEG          NEG
            -   13908000.           NEG       -   .035           NEG          NEG
406002000   +   41372000.           NEG       +   .114           NEG          NEG
            -   13068000.           NEG       -   .123           NEG          NEG
```

MSCC	Source Category	Charge Rate Unit
406000000	Petroleum Marketing and Transportation	1000 gal/yr
406001000	Rail and truck transportation	1000 gal/yr
406002000	Marine vessel transportation	1000 gal/yr

The major source categories summarized here are further classified and detailed in Sections II through X.

1.4 DATA ACQUISITION

1.4.1 Data Selected for Study

It was determined at the outset, by EPA, that this study would be restricted to stationary sources of emissions and that the emissions of interest were oxides of nitrogen (NO_x), carbon monoxide (CO), hydrocarbons (HC), and particulate matter (PART). It was also agreed that only point sources (as opposed to area sources) of emissions would be studied. A point source, as defined by the National Emissions Data System (NEDS), is a single stack or geographical point from which more than 100 tons of a given identified air pollutant are discharged annually into the atmosphere. The NEDS is described in detail in Ref. 1-1. The processes which contribute to the atmospheric emissions studied and reported here are described in Refs. 1-2 and 1-3.

The categories of emission sources initially selected for study were determined from the NEDS nationwide emissions report (Ref. 1-4). The order of priority was based largely on the desire to study as many stationary sources of the four emissions in as little time as possible. Table 1-7 shows the emissions from the categories selected for study. The values are as reported in the NEDS Nationwide Emissions Summary, January 10, 1975 (Ref. 1-4).

Table 1-7 shows that stationary area sources represent from 13 to 30 percent of the emissions of interest. The categories selected for study represent from 78 to 100 percent of the four point source emissions identified in Ref. 1-4.

Of the categories inventoried in the first year of this study, utility and industrial boilers and process gas combustion were studied together and are reported in Section II under the more general category "external combustion (boiler)." The process gas combustion category was included in this study because an earlier NEDS nationwide emissions summary (emissions as of December 19, 1973) indicated that nearly

Table 1-7. STUDY LIST OF EMISSIONS[a]

Source Category	Percent of Total Stationary Source Emissions			
	NO_x	HC	CO	PART
Utility Boilers	48.4	0.8	0.8	23.1
Industrial Boilers	9.6	0.9	1.0	9.8
Process Gas Combustion	0.9	-	-	0.1
Stationary IC Engines[b]	2.6	0.5	0.1	0.1
Petroleum Industry	22.6	9.7	13.9	6.6
Chemical Manufacturing	1.1	22.3	18.4	1.5
Evaporation	-	30.8	-	0.1
Primary Metals	0.1	1.1	24.3	10.1
Mineral Products	1.4	0.1	0.1	25.4
Secondary Metals	0.1	-	4.1	1.1
Wood Products	0.1	0.2	2.8	2.9
Point Source Emissions Selected for Study	86.9	66.4	65.5	80.8
Remaining Point Source Emissions	-	3.6	18.0	4.7
Total Area Source Emissions	13.1	30.0	16.5	14.5
Total Stationary Source Emissions	100.0	100.0	100.0	100.0

[a] Data extracted from Ref. 1-4, dated January 1975.

[b] Internal combustion (IC) engines.

20 percent of all NO_x from stationary sources originated from process gas combustion. This information was supported by the large process gas combustion rates listed in Ref. 1-4. Study of the actual data stored in the NEDS (from a data tape) showed that large errors in the original data for two users of process gases accounted for nearly all of the previously reported nationwide process gas usage rates and, therefore, for nearly all of the reported NO_x emissions in this category. These errors were reported, checked, and confirmed by the NEDS personnel, and greatly reduced NO_x emissions are now as reported in Table 1-7.

The stationary internal combustion engines category, although contributing only small quantities of emissions (Ref. 1-4), was chosen because the NO_x emissions could be very large, depending on the usage rates of a large population (Ref. 1-5) of gasoline-fueled engines, each of which is too small to be classed as a point source. Although emissions from point sources in this category are small, the data are summarized, along with a discussion of this critical area source problem, in Section III.

The chemical manufacturing and petroleum refinery categories were selected because of the high emissions of NO_x, CO, and HC. These categories are reported in Sections IV and V, respectively.

Although the categories under study have been referred to as NEDS categories, the NEDS was not the only source, or even in some cases the major source, of original data. Extensive reviews of the literature were also conducted to obtain other original data as well as the rationale for projection of the data into the future. The data obtained, consisting of necessary calculations, sources, and results, are different for each of the general categories studied, and discussions of these data are contained in each of the following sections of this report. The NEDS data acquisition and evaluation techniques were generally common to all categories studied.

1.4.2 Preliminary NEDS Data Evaluation

In each study, a computer tape of all point source data stored in the NEDS for the categories of interest were requested from EPA. Initially the data contained on the tape were analyzed (by computer) to determine the significant Source Classification Code (SCC). The NEDS SCC is listed and described in Appendix A. 2 of Ref. 1-1. This summary of emissions by the NEDS SCC was reviewed to determine those categories containing the bulk of the four emissions. In most cases it was found that a small number of SCC categories accounted for nearly all of the emissions of each type in the general category chosen for study. Therefore, the total of emissions of some types for the entire general category chosen for study was comparatively insignificant Considering the rather large ranges of uncertainty in the emissions from other major categories, it was not considered cost-effective to study these small categories. A general measure used to rule out study of certain emissions within a general category or to rule out study of certain SCCs altogether was based on one percent of the total stationary point source emissions. If the sum of any one of the four selected air pollution emissions over the entire general category was less than one percent, emissions of that pollutant were neglected. In certain groups of SCCs, none of the four emissions exceeded one percent, and these SCCs were neglected.

Reference 1-1 lists all the SCCs represented on the NEDS data tape in each of the general categories selected for study. Each data section in this report shows those SCCs studied. The SCCs listed in the appropriate category in Ref. 1-1 but not listed in the corresponding data section of this report were neglected for the above reasons. In cases where any of the four air pollutants were negligible, the data printout indicates "neg" (negligible).

The SCCs which were considered significant for one or more of the emissions were then reviewed for data entries indicating excessive process charge rates or emissions. The most commonly used technique to check charge rates was to review the process state of the art, select a large processing plant, and execute a computer search for point sources with listed charge rates greater than this expected maximum. If such cases were discovered, all of the data for that plant and point source were printed for further review. Many cases were found, in this manner, where the listed charge rates were 100 to 1000 times that considered reasonable for a large plant (in some cases even larger than the entire national capacity). In most categories, no equivalent reliable check could be devised, however, for charge rates listed too low. After correction of the data for charge rates listed too high, the corrected total was compared with other original data from the literature.

Erroneously recorded emissions were checked by comparing emission factors calculated from the NEDS tape data on emissions and charge rates against the latest emission factors recorded in Ref. 1-2. Some errors in the listed emissions were uncovered in this manner. A more common error, however, resulted from the accepted practice of calculating the emissions from the best estimate of emission factors and the charge rate, instead of from actual measurements. Since most of the data currently stored in the NEDS was entered in the 1970 through 1972 time period, emission factors were approximately those listed in Ref. 1-3. Corrections in emission factors between the Ref. 1-3 listing and the subsequent listing in Ref. 1-2 in some cases increased or decreased the emission factors by factors of as much as 75 and 40, respectively.

1.4.3 Data Coding

The NEDS data categories are identified by an eight-digit number called the SCC. Where possible and where one or more emissions in a given SCC were large, a further detailed breakdown of the data in that SCC was effected. To facilitate handling of this more detailed data and yet maintain close correspondence with the established NEDS SCC data coding system, a modified SCC (MSCC) system was initiated for this study. A ninth digit was added to all of the eight-digit NEDS SCCs to form the MSCCs used in this study. All of the NEDS SCCs, then, appear in this study with an additional zero in the last place of a nine-digit code number. Where additional breakdown of data in a NEDS SCC was possible and desirable, the last place in the nine-digit code of this study shows a nonzero digit. For example, the NEDS SCC category of 1-01-002-02 identifies raw, original data stored for the category: external combustion, boiler (1-xx-xxx-xx); electric generation (1-01-xxx-xx); bituminous coal (1-01-002-xx); fired as pulverized coal in dry-bottom boilers of capacity greater than 100 million Btu/hr (1-01-002-02). This same general category is identified in this study by the MSCC 101002020. This MSCC, in this study, however, is considered a fourth-level summary because the additional breakdowns 101002021 through 101002024 have been included to divide those data into the boiler firing types: tangential, opposed, single-wall, and vertical, respectively. These are now the data levels, and the MSCC 101002020 represents the sum of the emissions and charge rates of the four data SCCs. Where practical the process assigned to each MSCC was the same as that assigned by the NEDS to the corresponding SCC. In any case, the process corresponding to each MSCC is defined in the first table of the respective sections.

Although the data coding system used in this study closely parallels that of the NEDS system, the data actually stored and used in this study were acquired from a number of sources (including NEDS). The original data base being accumulated in the data storage and handling program at The Aerospace Corporation, then, represents a careful and judicious sum from other sources as well as NEDS.

1.5 DATA HANDLING AND STORAGE

The sheer volume of data being generated in this study immediately dictates the use of a computer system for storage and handling. A total of 413 MSCC data categories have been defined for storage of significant data. In each of the MSCCs, 40 separate items of information must be entered into storage. In any particular MSCC, a particular storage location may contain data either in the form of a number or an indication that the particular data are negligible. Thus, a total of more than 16,000 entries were entered into the program.

The general form of the data storage and handling program is based on two major considerations:

a. The data acquired from various sources represent different points in time. Particularly because of the rapidly changing energy picture, much of those data may have changed considerably between the time of acquisition and the time of this study. Data acquired and stored in general categories at the beginning of this study were three years older at the time of the first update. Users of the data need to have available an estimate of emissions in the time period of implementation of control systems (i.e., in the future) rather than at the time of planning.

b. Complete and accurate original data are difficult to acquire. As a result, little good data are available, and data from several sources are often widely discrepant. As estimates of future emissions are highly desirable, it is important to know how uncertain these projections are.

1.5.1 Data Projections

In response to the need for current and future emissions estimates as well as a set of values upon which these estimates and projections can be evaluated as to their accuracy, a data storage and handling program was developed. As in the NEDS summary system, emissions of each of the four air pollutants NO_x, CO, HC, and PART are calculated from charge rates and emission factors as shown in eq. (1-1):

$$\text{Emissions} = \text{Emission Factor} \times \text{Charge Rate} \qquad (1\text{-}1)$$

For all four of the emissions in a single SCC, the charge rate is the same and is fundamental data in itself. For that reason, storage space is available for three values of the charge rate (with the appropriate year of the data) for each MSCC.

For NO_x, CO, and HC emissions, the appropriate emission factors are entered directly and used with the charge rates as in Eq. (1-1) to calculate emissions. As such, these emission factors directly reflect the average degree of control of emissions in all processes represented by the MSCC. Since the degree of control may change with time, either because of more effective control or more widespread application of the same degree of control, the emission factor must be projected into the future independently of the charge rates.

Particulate (PART) emissions, however, are normally controlled by special hardware. Since these are recognizable pieces of hardware with relatively well-established PART collection efficiencies, both the collector efficiency and the degree of application of such collectors to processes represented in the MSCC can be determined. The emission factors in Eq. (1-1) for PART emissions, then, are calculated from an uncontrolled emission factor for the process and a function of the average collector efficiency and the average degree of application of this average collector:

$$\text{PART Emission Factor} = \text{Uncontrolled Emission Factor} \times (1 - \text{Collector Efficiency} \times \text{Fraction of Application of the Collector}) \qquad (1\text{-}2)$$

It is assumed that the uncontrolled PART emission factor is fundamental to the process and will not change with time. Both the average collector efficiency and the degree of application of this average collector, however, can change with time, and both must be projected independently into the future.

Thus, six time-dependent variables must be entered into the program storage in order to calculate emissions of the four air pollutants of interest: the latest charge rate, the three controlled emission factors, the PART collector efficiency, and the degree of application of the PART collector. Because of the widely varying sources of these data, they hardly ever represent the same period in time. Therefore, the original data cannot be meaningfully combined directly to calculate emissions. The data storage and handling program allows for three separate years of record for (1) the latest charge rate, (2) all three controlled emission factors and the PART control efficiency, and (3) the degree of PART control application. Whenever emissions are calculated, according to Eqs. (1-1) and (1-2), these time-dependent variables must be projected from their individual years of record to the same date.

The projection of these six time-dependent variables into the future required a time-dependent projection equation. In light of the large uncertainties in the original data and the usual uncertainties of the future, no more sophisticated equation than a straight line is justified. Thus, for each of the six time-dependent variables, a linear slope with time (a time derivative) must also be determined from appropriate rationale and stored in the data storage and handling program. All calculations of emissions thus start with the original data for the six time-dependent variables, use the six appropriate linear slopes to project these variables to some common time, and then calculate emissions from the projected values according to Eqs. (1-1) and (1-2). In this report, the current charge rate and emissions raw data base are generated by projecting all of the data to the current year. A further projection is made for five years into the future.

1.5.2 Data Uncertainties

The second major consideration in the development of the data storage and handling program relates to the uncertainties in the data. As related in Section 1.4.1, data have been found that were in error by two and three orders of magnitude. Differences between independent original sources of the same data are often as large as factors of two. The recent wide variations in charge rates with time, resulting first from the impact of environmental considerations and then from the energy shortage, make projections into the future uncertain. If users of the data reported here intend to give weight to certain emissions projected for different sources, then it becomes important that the user have values of the uncertainty in those emissions.

Even an estimate of the uncertainties in the data is difficult because of the lack of data. Adequate data are not available from a sufficient number of original sources that a reasonable statistical estimate of uncertainty can be made. The use of small data sample statistics results in unrealistically large uncertainties. In most cases, only two sources (and sometimes only one source) are available.

Usually, however, certain engineering methods can be followed in estimating realistic bounds on some given data or time-dependent slope from better-known data. For example, current levels of total electrical demand and total installed electric-generating capacity are reasonably widely studied and well documented. By using engineering judgment to set various realistic upper and lower bounds on less well-documented data, such as a breakdown of electric-generating capacity into fuels, firing types, and plant sizes, an engineering estimate of a reasonable uncertainty range around the data on charge rates in large pulverized coal-fired, electric-generating boilers can be obtained. It may also be possible, from a description of a particular study or survey, to make an engineering estimate of the degree of completeness and accuracy of the results. Some cases remain where no data other than a single estimate from the literature and the corresponding NEDS data are available. In such cases, there is no alternative other than to take the data as the average of the two available estimates and the uncertainty range as the difference between the two.

Some fairly clear limits exist, or are defined here, on projections into the future. In most cases, Aerospace familiarity with the basic processes generating or controlling emissions is sufficient that lower limits on emission factors can be estimated with reasonable confidence, at least for the near future. These lower limits are stored in the data storage and handling program, and the program will not allow the NO_x, CO, or HC emission factors (minus the uncertainty) to drop below these limits. Similarly, upper limits are set on PART collector efficiencies. The degree of application of a collector cannot exceed 1.0. Because of the social pressure in all areas to reduce air pollution, the assumption was made in this program that the maximum value of a projected emission factor (the projected nominal value plus the projected uncertainty) cannot exceed the current maximum value (i.e., no increase in emission factors). Of course, no charge rates or emissions, including uncertainties, are allowed to be negative. Limits such as those discussed in this paragraph can result in unsymmetrical uncertainties in projected data levels. For example, the 1977 NO_x emission for MSCC 101004000 is

$$0.641 \begin{matrix} +0.195 \\ -0.141 \end{matrix} \text{ (MILLIONS OF TONS PER YEAR).}$$

The above discussion outlines the methods used and problems encountered in generating engineering estimates of uncertainty in the data shown in this report. The fact that it is so difficult to generate these estimates underlines the need to provide the user with the documentation of the uncertainty of these data. These uncertainties are not statistical quantities. It is necessary, however, to combine the uncertainty estimates of charge rate, emission factor, collector efficiency, control equipment application data, and the derivatives of these with time (slopes) to establish the uncertainties of emission data projected into the future. In the data storage and handling program, these are treated as statistical quantities (standard deviation). The resulting uncertainties in the projected emissions are considered engineering estimates.

1.6 REFERENCES

1-1. Guide for Compiling a Comprehensive Emission Inventory, revised, APTD-1135, U. S. Environmental Protection Agency, Research Triangle Park, North Carolina (March 1973).

1-2. Compilation of Air Pollutant Emission Factors, AP-42, 2nd ed. (and supplements), U. S. Environmental Protection Agency, Research Triangle Park, North Carolina (April 1973).

1-3. Compilation of Air Pollutant Emission Factors, AP-42, U. S. Environmental Protection Agency, Research Triangle Park, North Carolina (February 1972).

1-4. Nationwide Emissions Summary, National Emissions Data System, U. S. Environmental Protection Agency, Research Triangle Park, North Carolina (January 10, 1975).

1-5. W. U. Roessler, et al, Assessment of the Applicability of Automotive Emission Control Technology to Stationary Engines, EPA-65012-74-051, The Aerospace Corporation, El Segundo, California (July 1974).

SECTION II

EXTERNAL COMBUSTION IN BOILERS

2.1 INTRODUCTION

The external combustion (boiler) category of stationary emission sources includes all of the fuels burned in stationary boilers for the purpose of generating steam for electric generation and various other industrial purposes. According to the National Emissions Data System (NEDS) nationwide emissions report of January 10, 1975 (Ref. 2-1), this category, at least in the 1970 to 1973 time period, represented the largest single stationary source of both oxides of nitrogen (NO_x) and particulate (PART) emissions. NO_x emissions of over 8 million tons per year represented about 59 percent of NO_x emissions from all stationary sources and about 36 percent of NO_x emissions from all sources inventoried by the NEDS. PART emissions of over 5 million tons per year represented about 33 percent of PART emissions from all stationary sources and 31 percent of this air pollutant emitted from all sources. Hydrocarbon (HC) and carbon monoxide (CO) emissions from sources in this category represented less than two percent, each, of those from all stationary sources. The external combustion (boiler) category was the first to be studied in this continuing inventory because of the large NO_x and PART emissions.

A wide range of fuels is burned in external combustion boilers, including the following:

a. Coal: anthracite, bituminous, and lignite
b. Oil: residual and distillate

c. Gas: natural and processed
d. Wood
e. Bagasse
f. Coke
g. Liquified petroleum gas
h. Other minor fuels

Of the NO_x and PART generated from the external combustion of these fuels, for electric generation and various purposes, in single sources emitting more than 100 tons per year of these air pollutants (point sources), the combustion of bituminous coal is by far the largest fuel source. More than 58 and 88 percent of the NO_x and PART, respectively, from the external combustion, boiler category result from the combustion of bituminous coal. Other fuel combustion which contributes significantly to the emission of NO_x and PART includes that of natural gas and oil.

At the time that the fuels to be studied in this portion of the inventory were selected, the then existing NEDS emission summary (dated December 19, 1973) indicated that process gas combustion in industrial boilers and heaters was the source of 2.6 million tons per year of NO_x and resulted from the annual combustion of more than 2×10^{13} cu ft/year of such gaseous fuels. This fuel category, therefore, was included in those to be studied. During the study, it was found that large errors in the fuel usage (annual charge rate) data submitted by two companies accounted for over 90 percent of the listed annual process gas combustion and more than 80 percent of the listed NO_x emissions from process gas combustion. These errors have subsequently been corrected in the NEDS data bank. The NEDS emissions inventory of January 10, 1975 (Ref. 2-1) indicates only about 11,000 tons per year of NO_x from combustion of process gas. Since this fuel category was studied, however, it is included in the projections in this section even though the emissions are small or negligible. No significant effort was made to estimate future changes in process gas usage rates or emission factors.

The fuels selected for study in this inventory were bituminous coal, residual and distillate oil, natural gas, and process gas. These five fuels account for 96 and 92 percent, respectively, of the NO_x and PART generated from external combustion, electric generation, and industrial point sources. All other fuels except lignite and wood represent sources of less than one percent of these pollutants. Lignite represents the source of just over one percent of the pollutants from this category and was neglected. Wood combustion represents the source of nearly two percent and more than four percent of the NO_x and PART, respectively, from this category. The more general category of wood products, including wood combustion, also represents a significant source of CO emissions.

2.2 SUMMARY

The NEDS Source Classification Code (SCC) for external combustion (boiler) point source categories was modified according to the fuels utilized in utility and industrial boilers and inventoried by this study. Table 2-1, therefore, identifies the source categories studied according to the Aerospace-developed Modified Source Classification Code (MSCC) and presents the total annual charge rate projected (TACRP) unit for each.

A summary of the 1977 and 1982 emissions and charge rates for the external combustion (boiler) categories was compiled and is given in Tables 2-2-a and 2-3-a, respectively. The uncertainties in the emission and charge rate data for 1977 and 1982 are given in Tables 2-2-b and 2-3-b, respectively.

2.3 APPROACH

Study of fuel usage, emission factors, and projection data in the external combustion (boiler) category was initiated in this study solely from the available literature. In many areas, however, the available data did not provide a sufficient breakdown of firing types nor sufficient multiple sources to evaluate data accuracy (or uncertainty). As a result, a computer tape was obtained from the NEDS data bank containing card images of all stored point source data for utility and industrial boilers,

(Continued on page 2-24)

Table 2-1. Definition of External Combustion (Boiler) Processes

MSCC	Source Category	TACRP Unit
101000000	Utility Boilers	
101002000	Bituminous coal	Tons/yr
101002010	>100 MMBtu/hr pulverized wet	Tons/yr
101002020	>100 MMBtu/hr pulverized dry	Tons/yr
101002021	Tangential firing	Tons/yr
101002022	Opposed firing	Tons/yr
101002023	Single-wall firing	Tons/yr
101002024	Vertical firing	Tons/yr
101002030	>100 MMBtu/hr cyclone	Tons/yr
101002040	>100 MMBtu/hr spreader stoker	Tons/yr
101002050	>100 MMBtu/hr overfeed stoker	Tons/yr
101002060	10 to 100 MMBtu/hr pulverized wet	Tons/yr
101002070	10 to 100 MMBtu/hr pulverized dry	Tons/yr
101002080	10 to 100 MMBtu/hr overfeed stoker	Tons/yr
101002090	10 to 100 MMBtu/hr underfeed stoker	Tons/yr
101002100	<10 MMBtu/hr overfeed stoker	Tons/yr
101002110	<10 MMBtu/hr underfeed stoker	Tons/yr
101002120	<10 MMBtu/hr pulverized dry	Tons/yr
101004000	Residual oil	1000 gal/yr
101004010	>100 MMBtu/hr general	1000 gal/yr
101004011	Tangential firing	1000 gal/yr
101004012	Opposed firing	1000 gal/yr

Table 2-1. Definition of External Combustion (Boiler) Processes (Continued)

MSCC	Source Category	TACRP Unit
101004013	Single-wall firing	1000 gal/yr
101004014	Vertical firing	1000 gal/yr
101004020	10 to 100 MMBtu/hr general	1000 gal/yr
101004030	<10 MMBtu/hr general	1000 gal/yr
101005000	Distillate oil	1000 gal/yr
101005010	>100 MMBtu/hr general	1000 gal/yr
101005020	10 to 100 MMBtu/hr general	1000 gal/yr
101005030	<10 MMBtu/hr general	1000 gal/yr
101006000	Natural gas	Million cu ft/yr
101006010	>100 MMBtu/hr general	Million cu ft/yr
101006011	Tangential firing	Million cu ft/yr
101006012	Opposed firing	Million cu ft/yr
101006013	Single wall firing	Million cu ft/yr
101006014	Vertical firing	Million cu ft/yr
101006020	10 to 100 MMBtu/hr general	Million cu ft/yr
101006030	<10 MMBtu/hr general	Million cu ft/yr
101007000	Process gas	Million cu ft/yr
101007010	>100 MMBtu/hr general	Million cu ft/yr
101007020	10 to 100 MMBtu/hr general	Million cu ft/yr
101007030	<10 MMBtu/hr general	Million cu ft/yr

Table 2-1. Definition of External Combustion (Boiler) Processes (Continued)

MSCC	Source Category	TACRP Unit
102000000	Industrial Boilers	
102002000	Bituminous coal	Tons/yr
102002010	>100 MMBtu/hr pulverized wet	Tons/yr
102002020	>100 MMBtu/hr pulverized dry	Tons/yr
102002030	>100 MMBtu/hr cyclone	Tons/yr
102002040	>100 MMBtu/hr spreader stoker	Tons/yr
102002050	10 to 100 MMBtu/hr overfeed stoker	Tons/yr
102002060	10 to 100 MMBtu/hr underfeed stoker	Tons/yr
102002070	10 to 100 MMBtu/hr wet pulverized	Tons/yr
102002080	10 to 100 MMBtu/hr dry pulverized	Tons/yr
102002090	10 to 100 MMBtu/hr spreader stoker	Tons/yr
102002100	<10 MMBtu/hr overfeed stoker	Tons/yr
102002110	<10 MMBtu/hr underfeed stoker	Tons/yr
102002120	<10 MMBtu/hr dry pulverized	Tons/yr
102002130	<10 MMBtu/hr spreader stoker	Tons/yr
102004000	Residual-oil-fired	1000 gal/yr
102004010	>100 MMBtu/hr residual-oil-fired	1000 gal/yr
102004020	10 to 100 MMBtu/hr residual-oil-fired	1000 gal/yr
102004030	<10 MMBtu/hr residual-oil-fired	1000 gal/yr

Table 2-1. Definition of External Combustion (Boiler) Processes (Continued)

MSCC	Source Category	TACRP Unit
102005000	Distillate-oil-fired	
102005010	>100 MMBtu/hr distillate-oil-fired	1000 gal/yr
102005020	10 to 100 MMBtu/hr distillate-oil-fired	1000 gal/yr
102005030	<10 MMBtu/hr distillate-oil-fired	1000 gal/yr
102006000	Natural-gas-fired	
102006010	>100 MMBtu/hr natural-gas-fired	Million cu ft/yr
102006020	10 to 100 MMBtu/hr natural-gas-fired	Million cu ft/yr
102006030	<10 MMBtu/hr natural-gas-fired	Million cu ft/yr
102007000	Process gas-fired	
102007010	>100 MMBtu/hr process gas-fired	Million cu ft/yr
102007020	10 to 100 MMBtu/hr process-gas-fired	Million cu ft/yr
102007030	<10 MMBtu/hr process-gas-fired	Million cu ft/yr

Million British thermal units (MMBtu).

Table 2-2-a. 1977 EXTERNAL COMBUSTION EMISSIONS AND CHARGE RATES

EXTERNAL COMBUSTION, BOILER CATEGORY

ANNUAL CHARGE RATES AND EMISSIONS PROJECTED TO 1977 PAGE 1

RUN DATE= NOV 16,1977

MODIFIED SCC	TACRF (SCC UNITS)	NOX	HC	CO	PART
		EMISSIONS (MILLIONS OF TONS / YEAR)			
101002000	438640000.	5.081	.080	.226	4.381
101002010	48600000.	.559	.007	.024	.806
101002020	313260000.	2.851	.057	.157	3.099
101002021	164800000.	1.020	.025	.082	1.630
101002022	66500000.	.820	.010	.033	.658
101002023	65700000.	.810	.010	.033	.650
101002024	16260000.	.200	.012	.008	.161
101002030	60000000.	1.548	.009	.030	.212
101002040	5170000.	.035	.003	.005	.098
101002050	2730000.	.019	.001	.003	.036
101002060	190000.	.002	.000	.000	.006
101002070	1738000.	.016	.000	.001	.024
101002080	1180000.	.008	.001	.001	.016
101002090	3740000.	.026	.002	.004	.033
101002100	140000.	.001	.000	.001	.001
101002110	0.	.000	.000	.000	.000
101002120	1896000.	.017	.000	.001	.051
101004000	24200000.	.631	.024	.036	.097
101004010	23629000.	.617	.024	.035	.095
101004011	9410000.	.147	.009	.014	.038
101004012	6690000.	.209	.007	.010	.027
101004013	6690000.	.209	.007	.010	.027
101004014	839000.	.052	.001	.001	.003
101004020	420000.	.011	.000	.001	.002
101004030	150700.	.004	.000	.000	.001
101005000	0.	0.000	0.000	0.000	0.000
101005010	0.	0.000	0.000	0.000	0.000
101005020	0.	0.000	0.000	0.000	0.000
101005030	0.	0.000	0.000	0.000	0.000

Table 2-2-a. 1977 EXTERNAL COMBUSTION EMISSIONS AND CHARGE RATES (Continued)

EXTERNAL COMBUSTION, BOILER CATEGORY PAGE 2

ANNUAL CHARGE RATES AND EMISSIONS PROJECTED TO 1977 RUN DATE= NOV 16,1977

MODIFIED SCC	TACRF (SCC UNITS)	EMISSIONS (MILLIONS OF TONS / YEAR) NOX	HC	CO	PART
101006000	2597200.	.415	.001	.022	.019
101006010	2551500.	.408	.001	.022	.019
101006011	675000.	.060	.000	.006	.005
101006012	1050000.	.187	.001	.009	.008
101006013	750000.	.134	.000	.006	.006
101006014	76500.	.027	.000	.001	.001
101006020	45700.	.007	.000	.000	.000
101006030	0.	0.000	0.000	0.000	0.000
101007000	90390.	.000	NEG	NEG	NEG
101007010	90390.	.000	NEG	NEG	NEG
101007020	NEG	NEG	NEG	NEG	NEG
101007030	NEG	NEG	NEG	NEG	NEG
102002000	107910000.	1.043	.050	.123	1.774
102002010	1272000.	.015	.000	.001	.019
102002020	14000000.	.127	.002	.007	.271
102002030	14530000.	.375	.002	.007	.066
102002040	25700000.	.176	.013	.026	.491
102002050	2730000.	.019	.001	.003	.059
102002060	11570000.	.079	.006	.012	.179
102002070	2790000.	.030	.000	.001	.122
102002080	0.	0.000	0.000	0.000	0.000
102002090	25900000.	.178	.013	.026	.446
102002100	3040000.	.012	.005	.015	.017
102002110	1290000.	.001	.002	.006	.015
102002120	1437000.	.013	.000	.001	.057
102002130	3650000.	.019	.005	.018	.033
102004000	18220000.	.328	.027	.042	.210
102004010	7310000.	.132	.011	.015	.084
102004020	7580000.	.136	.011	.021	.087

Table 2-2-a. 1977 EXTERNAL COMBUSTION EMISSIONS AND CHARGE RATES (Continued)

EXTERNAL COMBUSTION, BOILER CATEGORY PAGE 3

ANNUAL CHARGE RATES AND EMISSIONS PROJECTED TO 1977 RUN DATE= NOV 16,1977

MODIFIED SCC	TACRP (SCC UNITS)	EMISSIONS (MILLIONS OF TONS / YEAR) NOX	HC	CO	PART
102004030	3330000.	.060	.005	.007	.038
102005000	6720000.	.121	.010	.013	.050
102005010	3120000.	.056	.005	.006	.023
102005020	1740000.	.031	.003	.003	.013
102005030	1860000.	.033	.003	.004	.014
102006000	5011000.	.386	.008	.043	.045
102006010	2230000.	.172	.003	.019	.020
102006020	1850000.	.142	.003	.016	.017
102006030	931000.	.072	.001	.008	.008
102007000	1749300.	.000	NEG	NEG	NEG
102007010	1257000.	.000	NEG	NEG	NEG
102007020	464000.	.000	NEG	NEG	NEG
102007030	28260.	.000	NEG	NEG	NEG

Table 2-2-b. 1977 EXTERNAL COMBUSTION UNCERTAINTIES

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                         EXTERNAL COMBUSTION, BOILER CATEGORY                    PAGE  1
TACR AND EMISSION UNCERTAINTIES PROJECTED TO 1977       RUN DATE= NOV 16,1977
 MODIFIED         TACRP              EMISSIONS (MILLIONS OF TONS / YEAR)
   SCC        (SCC UNITS)       NOX              HC              CO              PART
101002000   +    9195800.    +  .449       +  .110       +  .077       +  .538
            -    9146500.    -  .449       -  .016       -  .052       -  .538

101002010   +    1565200.    +  .115       +  .006       +  .018       +  .263
            -    1565200.    -  .115       -  .004       -  .012       -  .263
101002020   +    8687300.    +  .324       +  .110       +  .071       +  .460
            -    8687300.    -  .324       -  .014       -  .048       -  .460

101002021   +    8209800.    +  .215       +  .019       +  .062       +  .400
            -    8209800.    -  .215       -  .012       -  .041       -  .400
101002022   +    1924200.    +  .170       +  .076       +  .025       +  .159
            -    1924200.    -  .170       -  .005       -  .017       -  .159
101002023   +    1924200.    +  .168       +  .076       +  .025       +  .157
            -    1924200.    -  .168       -  .005       -  .016       -  .157
101002024   +     815410.    +  .042       +  .009       +  .006       +  .040
            -     815410.    -  .042       -  .001       -  .004       -  .040

101002030   +    1831000.    +  .289       +  .007       +  .023       +  .065
            -    1831000.    -  .289       -  .005       -  .015       -  .065
101002040   +     692310.    +  .008       +  .002       +  .004       +  .033
            -     692310.    -  .008       -  .002       -  .003       -  .032
101002050   +     152710.    +  .003       +  .001       +  .002       +  .016
            -     152710.    -  .003       -  .001       -  .001       -  .016
101002060   +      56685.    +  .001       +  .000       +  .000       +  .004
            -      56685.    -  .001       -  .000       -  .000       -  .004
101002070   +     681690.    +  .007       +  .000       +  .001       +  .010
            -     681690.    -  .007       -  .000       -  .001       -  .010
101002080   +     680140.    +  .005       +  .001       +  .001       +  .010
            -     680140.    -  .005       -  .001       -  .001       -  .010
101002090   +     683910.    +  .007       +  .001       +  .003       +  .016
            -     683910.    -  .007       -  .001       -  .002       -  .016
101002100   +     680000.    +  .003       +  .001       +  .003       +  .003
            -     140000.    -  .001       -  .000       -  .001       -  .001
101002110   +     680000.    +  .002       +  .001       +  .003       +  .003
            -          0.    -  .000       -  .000       -  .000       -  .000
101002120   +     682060.    +  .007       +  .000       +  .001       +  .051
            -     682060.    -  .007       -  .000       -  .001       -  .051
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Table 2-2-b. 1977 EXTERNAL COMBUSTION UNCERTAINTIES (Continued)

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                    EXTERNAL COMBUSTION, BOILER CATEGORY                  PAGE  2
 TACR AND EMISSION UNCERTAINTIES PROJECTED TO 1977      RUN DATE= NOV 16,1977
 MODIFIED          TACRF                  EMISSIONS (MILLIONS OF TONS / YEAR)
   SCC.        (SCC UNITS)           NOX              HC              CO           PART

101004000   +    4911500.       +  .195       +  .011       +  .017       +  .020
            -    3609100.       -  .141       -  .008       -  .011       -  .014

101004010   +    4015300.       +  .191       +  .011       +  .017       +  .016
            -    3581400.       -  .141       -  .008       -  .011       -  .014

101004011   +    2014300.       +  .051       +  .007       +  .011       +  .008
            -    2014300.       -  .051       -  .005       -  .008       -  .008
101004012   +    2008100.       +  .085       +  .005       +  .008       +  .008
            -    2008100.       -  .085       -  .004       -  .006       -  .008
101004013   +    2008100.       +  .085       +  .005       +  .008       +  .008
            -    2008100.       -  .085       -  .004       -  .006       -  .008
101004014   +    2000000.       +  .126       +  .002       +  .003       +  .008
            -     839000.       -  .052       -  .001       -  .001       -  .003

101004020   +    2000000.       +  .051       +  .002       +  .003       +  .008
            -     420000.       -  .011       -  .000       -  .001       -  .002
101004030   +    2000000.       +  .051       +  .002       +  .003       +  .008
            -     150700.       -  .004       -  .000       -  .000       -  .001

101005000   +          0.       + 0.000       + 0.000       + 0.000       + 0.000
            -          0.       - 0.000       - 0.000       - 0.000       - 0.000

101005010   +          0.       + 0.000       + 0.000       + 0.000       + 0.000
            -          0.       - 0.000       - 0.000       - 0.000       - 0.000
101005020   +          0.       + 0.000       + 0.000       + 0.000       + 0.000
            -          0.       - 0.000       - 0.000       - 0.000       - 0.000
101005030   +          0.       + 0.000       + 0.000       + 0.000       + 0.000
            -          0.       - 0.000       - 0.000       - 0.000       - 0.000

101006000   +     127590.       +  .039       +  .001       +  .009       +  .001
            -     125150.       -  .039       -  .000       -  .006       -  .001

101006010   +     116500.       +  .038       +  .001       +  .009       +  .001
            -     116500.       -  .038       -  .000       -  .006       -  .001

101006011   +      57271.       +  .009       +  .000       +  .004       +  .000
            -      57271.       -  .009       -  .000       -  .003       -  .000
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Table 2-2-b. 1977 EXTERNAL COMBUSTION UNCERTAINTIES (Continued)

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                    EXTERNAL COMBUSTION, BOILER CATEGORY                     PAGE  3
TACR AND EMISSION UNCERTAINTIES PROJECTED TO 1977        RUN DATE= NOV 16,1977
 MODIFIED          TACRF                EMISSIONS (MILLIONS OF TONS / YEAR)
   SCC          (SCC UNITS)        NOX              HC              CO              PART

101006012     +      64404.     +  .026       +  .000       +  .007       +  .000
              -      64404.     -  .026       -  .000       -  .004       -  .000
101006013     +      58591.     +  .020       +  .000       +  .005       +  .000
              -      58591.     -  .020       -  .000       -  .003       -  .000
101006014     +      52075.     +  .019       +  .000       +  .001       +  .000
              -      52075.     -  .019       -  .000       -  .001       -  .000

101006020     +      52027.     +  .008       +  .000       +  .001       +  .000
              -      45700.     -  .007       -  .000       -  .000       -  .000
101006030     +          0.     + 0.000       + 0.000       + 0.000       + 0.000
              -          0.     - 0.000       - 0.000       - 0.000       - 0.000

101007000     +      15220.     +  .000          NEG           NEG           NEG
              -      15220.     -  .000          NEG           NEG           NEG

101007010     +      15220.     +  .000          NEG           NEG           NEG
              -      15220.     -  .000          NEG           NEG           NEG
101007020            NEG             NEG         NEG           NEG           NEG
                     NEG             NEG         NEG           NEG           NEG
101007030            NEG             NEG         NEG           NEG           NEG
                     NEG             NEG         NEG           NEG           NEG

102002000     +    2283400.     +  .092       +  .015       +  .032       +  .252
              -    2283400.     -  .092       -  .015       -  .023       -  .252

102002010     +     636000.     +  .008       +  .000       +  .001       +  .010
              -     636000.     -  .008       -  .000       -  .000       -  .010
102002020     +     700000.     +  .027       +  .002       +  .005       +  .062
              -     700000.     -  .027       -  .001       -  .004       -  .062
102002030     +     726000.     +  .072       +  .002       +  .005       +  .019
              -     726000.     -  .072       -  .001       -  .004       -  .019
102002040     +    1290000.     +  .032       +  .010       +  .019       +  .127
              -    1290000.     -  .032       -  .010       -  .013       -  .127
102002050     +     136000.     +  .003       +  .001       +  .002       +  .013
              -     136000.     -  .003       -  .001       -  .001       -  .013
102002060     +     579000.     +  .015       +  .004       +  .009       +  .046
              -     579000.     -  .015       -  .004       -  .006       -  .046
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Table 2-2-b. 1977 EXTERNAL COMBUSTION UNCERTAINTIES (Continued)

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                    EXTERNAL COMBUSTION, BOILER CATEGORY                     PAGE  4
        TACR AND EMISSION UNCERTAINTIES PROJECTED TO 1977      RUN DATE= NOV 16,1977
 MODIFIED         TACRP                    EMISSIONS (MILLIONS OF TONS / YEAR)
   SCC         (SCC UNITS)          NOX              HC              CO              PART

102002070   +     140000.      +  .008      +  .000      +  .001      +  .037
            -     140000.      -  .008      -  .000      -  .001      -  .C37
102002080   +         0.       + 0.000      + 0.000      + 0.000      + 0.000
            -         0.       - 0.000      - 0.000      - 0.000      - 0.000
102002090   +    1300000.      +  .033      +  .010      +  .019      +  .196
            -    1300000.      -  .033      -  .010      -  .013      -  .196
102002100   +     152000.      +  .005      +  .002      +  .008      +  .013
            -     152000.      -  .005      -  .002      -  .008      -  .011
102002110   +      64000.      +  .004      +  .001      +  .003      +  .008
            -      64000.      -  .009      -  .001      -  .003      -  .008
102002120   +      72000.      +  .003      +  .000      +  .001      +  .024
            -      72000.      -  .003      -  .000      -  .000      -  .023
102002130   +     180000.      +  .013      +  .003      +  .009      +  .019
            -     180000.      -  .013      -  .003      -  .009      -  .018

102004000   +     705210.      +  .125      +  .013      +  .016      +  .008
            -     705210.      -  .125      -  .008      -  .013      -  .008

102004010   +     320000.      +  .083      +  .008      +  .010      +  .004
            -     320000.      -  .083      -  .006      -  .007      -  .004
102004020   +     550000.      +  .086      +  .009      +  .011      +  .006
            -     550000.      -  .086      -  .006      -  .011      -  .006
102004030   +     304000.      +  .038      +  .004      +  .005      +  .003
            -     304000.      -  .038      -  .003      -  .003      -  .003

102005000   +     198130.      +  .046      +  .005      +  .006      +  .001
            -     198130.      -  .046      -  .003      -  .004      -  .001

102005010   +      35000.      +  .035      +  .004      +  .004      +  .000
            -      35000.      -  .035      -  .002      -  .003      -  .000
102005020   +      84000.      +  .020      +  .002      +  .002      +  .001
            -      84000.      -  .020      -  .001      -  .002      -  .001
102005030   +     176000.      +  .021      +  .002      +  .003      +  .001
            -     176000.      -  .021      -  .001      -  .002      -  .001

102006000   +     198130.      +  .072      +  .004      +  .020      +  .002
            -     198130.      -  .112      -  .002      -  .013      -  .002
```

Table 2-2-b. 1977 EXTERNAL COMBUSTION UNCERTAINTIES (Continued)

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                 EXTERNAL COMBUSTION, BOILER CATEGORY                    PAGE  5

TACR AND EMISSION UNCERTAINTIES PROJECTED TO 1977        RUN DATE= NOV 16,1977

 MODIFIED           TACRF                EMISSIONS (MILLIONS OF TONS / YEAR)
   SCC           (SCC UNITS)          NOX             HC              CO             PART

102006010    +       35000.       +  .051       +  .003       +  .014       +  .000
             -       35000.       -  .081       -  .002       -  .009       -  .000
102006020    +       84000.       +  .043       +  .002       +  .012       +  .001
             -       84000.       -  .068       -  .001       -  .008       -  .001
102006030    +      176000.       +  .025       +  .001       +  .006       +  .002
             -      176000.       -  .036       -  .001       -  .004       -  .002

102007000    +      142990.       +  .000          NEG           NEG            NEG
             -      142990.       -  .000          NEG           NEG            NEG

102007010    +      125700.       +  .000          NEG           NEG            NEG
             -      125700.       -  .000          NEG           NEG            NEG
102007020    +       68100.       +  .000          NEG           NEG            NEG
             -       68100.       -  .000          NEG           NEG            NEG
102007030    +        2800.       +  .000          NEG           NEG            NEG
             -        2800.       -  .000          NEG           NEG            NEG
```

Table 2-3-a. 1982 EXTERNAL COMBUSTION EMISSIONS AND CHARGE RATES

EXTERNAL COMBUSTION, BOILER CATEGORY PAGE 1

ANNUAL CHARGE RATES AND EMISSIONS PROJECTED TO 1982 RUN DATE= NOV 16,1977

MODIFIED SCC	TACRF (SCC UNITS)	EMISSIONS (MILLIONS OF TONS / YEAR) NOX	HC	CO	PART
101002000	520000000.	4.767	.098	.272	4.130
101002010	50350000.	.453	.008	.025	.651
101002020	374410000.	2.746	.068	.187	3.028
101002021	196800000.	.982	.030	.098	1.592
101002022	79500000.	.789	.012	.040	.643
101002023	78700000.	.781	.012	.039	.636
101002024	19410000.	.193	.015	.010	.157
101002030	69000000.	1.418	.010	.035	.181
101002040	6920000.	.038	.003	.007	.094
101002050	4480000.	.024	.002	.004	.042
101002060	190000.	.002	.000	.000	.004
101002070	2083000.	.015	.000	.001	.024
101002080	2930000.	.016	.001	.003	.032
101002090	6990000.	.038	.003	.007	.045
101002100	390000.	.001	.001	.002	.001
101002110	0.	.000	.000	.000	.000
101002120	2261000.	.017	.000	.001	.027
101004000	31400000.	.115	.031	.047	.126
101004010	30129000.	.110	.030	.045	.121
101004011	11910000.	.043	.012	.018	.048
101004012	8190000.	.030	.008	.012	.033
101004013	8190000.	.030	.008	.012	.033
101004014	1839000.	.007	.002	.003	.007
101004020	770000.	.003	.001	.001	.003
101004030	500700.	.002	.001	.001	.002
101005000	0.	0.000	0.000	0.000	0.000
101005010	0.	0.000	0.000	0.000	0.000
101005020	0.	0.000	0.000	0.000	0.000
101005030	0.	0.000	0.000	0.000	0.000

Table 2-3-a. 1982 EXTERNAL COMBUSTION EMISSIONS AND CHARGE RATES (Continued)

EXTERNAL COMBUSTION, BOILER CATEGORY PAGE 2

ANNUAL CHARGE RATES AND EMISSIONS PROJECTED TO 1982 RUN DATE= NOV 16,1977

MODIFIED SCC	TACRF (SCC UNITS)	EMISSIONS (MILLIONS OF TONS / YEAR) NOX	HC	CO	PART
101006000	1232200.	.031	.001	.010	.009
101006010	1211500.	.030	.001	.010	.009
101006011	325000.	.008	.000	.003	.002
101006012	500000.	.013	.000	.004	.004
101006013	350000.	.009	.000	.003	.003
101006014	36500.	.001	.000	.000	.000
101006020	20700.	.001	.000	.000	.000
101006030	0.	0.000	0.000	0.000	0.000
101007000	90390.	.000	NEG	NEG	NEG
101007010	90390.	.000	NEG	NEG	NEG
101007020	NEG	NEG	NEG	NEG	NEG
101007030	NEG	NEG	NEG	NEG	NEG
102002000	145390000.	1.124	.066	.163	1.684
102002010	5277000.	.047	.001	.003	.058
102002020	18400000.	.134	.003	.009	.281
102002030	19105000.	.393	.003	.010	.061
102002040	33800000.	.184	.017	.034	.460
102002050	3480000.	.019	.002	.003	.049
102002060	15220000.	.083	.008	.015	.147
102002070	3670000.	.032	.001	.002	.092
102002080	0.	0.000	0.000	0.000	0.000
102002090	34050000.	.185	.017	.034	.392
102002100	3997000.	.013	.006	.020	.022
102002110	1695000.	.001	.003	.008	.017
102002120	1892000.	.014	.000	.001	.068
102002130	4800000.	.020	.007	.024	.037
102004000	21425000.	.078	.032	.050	.246
102004010	8595000.	.031	.013	.017	.099
102004020	8915000.	.033	.013	[illegible]	.103

Table 2-3-a. 1982 EXTERNAL COMBUSTION EMISSIONS AND CHARGE RATES (Continued)

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                    EXTERNAL COMBUSTION, BOILER CATEGORY                     PAGE  3
ANNUAL CHARGE RATES AND EMISSIONS PROJECTED TO 1982      RUN DATE= NOV 16,1977
 MODIFIED           TACRF                EMISSIONS (MILLIONS OF TONS / YEAR)
   SCC           (SCC UNITS)         NOX          HC            CO          PART
102004030          3915000.          .014         .006          .008         .045

102005000          7904500.          .029         .012          .016         .059

102005010          3670000.          .013         .006          .007         .028
102005020          2046500.          .007         .003          .004         .015
102005030          2188000.          .008         .003          .004         .016

102006000          5559000.          .303         .008          .047         .050

102006010          2473500.          .135         .004          .021         .022
102006020          2052500.          .112         .003          .017         .018
102006030          1033000.          .056         .002          .009         .009

102007000          1749300.          .000          NEG           NEG          NEG

102007010          1257000.          .000          NEG           NEG          NEG
102007020           464000.          .000          NEG           NEG          NEG
102007030            29260.          .000          NEG           NEG          NEG
```

Table 2-3-b. 1982 EXTERNAL COMBUSTION UNCERTAINTIES

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                      EXTERNAL COMBUSTION, BOILER CATEGORY                          PAGE  1
TACR AND EMISSION UNCERTAINTIES PROJECTED TO 1982        RUN DATE= NOV 16,1977
 MODIFIED          TACRP
   SCC          (SCC UNITS)               EMISSIONS (MILLIONS OF TONS / YEAR)
                                    NOX             HC              CO             PART
101002000   +   25840000.       +  .926      +  .132      +  .094      + 1.013
            -   25587000.       -  .926      -  .019      -  .062      - 1.012

101002010   +    2821800.       +  .219      +  .006      +  .019      +  .270
            -    2821800.       -  .219      -  .004      -  .013      -  .269
101002020   +   24724000.       +  .618      +  .131      +  .086      +  .969
            -   24724000.       -  .618      -  .017      -  .058      -  .970

101002021   +   24240000.       +  .416      +  .023      +  .075      +  .845
            -   24240000.       -  .416      -  .015      -  .051      -  .845
101002022   +    2984000.       +  .319      +  .091      +  .030      +  .333
            -    2984000.       -  .319      -  .006      -  .020      -  .333
101002023   +    2984000.       +  .316      +  .091      +  .030      +  .329
            -    2984000.       -  .316      -  .006      -  .020      -  .329
101002024   +    2422200.       +  .081      +  .011      +  .007      +  .083
            -    2422200.       -  .081      -  .002      -  .005      -  .083

101002030   +    2924800.       +  .653      +  .008      +  .026      +  .078
            -    2924800.       -  .653      -  .005      -  .017      -  .078
101002040   +    2383500.       +  .022      +  .003      +  .006      +  .057
            -    2383500.       -  .022      -  .003      -  .004      -  .054
101002050   +     493780.       +  .012      +  .002      +  .003      +  .025
            -     493780.       -  .012      -  .002      -  .002      -  .024
101002060   +     126400.       +  .001      +  .000      +  .000      +  .003
            -     126400.       -  .001      -  .000      -  .000      -  .004
101002070   +    2380500.       +  .018      +  .000      +  .001      +  .028
            -    2083000.       -  .015      -  .000      -  .001      -  .024
101002080   +    2380000.       +  .015      +  .002      +  .003      +  .028
            -    2380000.       -  .015      -  .001      -  .003      -  .029
101002090   +    2381100.       +  .022      +  .003      +  .006      +  .024
            -    2381100.       -  .022      -  .003      -  .004      -  .032
101002100   +    2380000.       +  .008      +  .004      +  .012      +  .007
            -     390000.       -  .001      -  .001      -  .002      -  .001
101002110   +    2380000.       +  .006      +  .004      +  .012      +  .007
            -          0.       -  .000      -  .000      -  .000      -  .000
101002120   +    2380600.       +  .019      +  .000      +  .001      +  .039
            -    2261000.       -  .017      -  .000      -  .001      -  .027
```

Table 2-3-b. 1982 EXTERNAL COMBUSTION UNCERTAINTIES (Continued)

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                          EXTERNAL COMBUSTION, BOILER CATEGORY                             PAGE  2
TACR AND EMISSION UNCERTAINTIES PROJECTED TO 1982           RUN DATE= NOV 16,1977
 MODIFIED          TACRF               EMISSIONS (MILLIONS OF TONS / YEAR)
   SCC          (SCC UNITS)        NOX               HC               CO              PART

101004000   +   17150000.     +  .213         +  .021         +  .032         +  .069
            -   12302000.     -  .045         -  .015         -  .022         -  .049

101004010   +   14004000.     +  .209         +  .019         +  .028         +  .056
            -   12268000.     -  .045         -  .015         -  .022         -  .049

101004011   +    7004100.     +  .093         +  .011         +  .017         +  .028
            -    7004100.     -  .026         -  .009         -  .014         -  .028
101004012   +    7002300.     +  .126         +  .009         +  .014         +  .028
            -    7002300.     -  .026         -  .008         -  .012         -  .028
101004013   +    7002300.     +  .125         +  .009         +  .014         +  .028
            -    7002300.     -  .026         -  .008         -  .012         -  .028
101004014   +    7000000.     +  .061         +  .007         +  .011         +  .028
            -    1839000.     -  .007         -  .002         -  .003         -  .007

101004020   +    7000000.     +  .027         +  .007         +  .011         +  .028
            -     770000.     -  .003         -  .001         -  .001         -  .003
101004030   +    7000000.     +  .026         +  .007         +  .011         +  .028
            -     500700.     -  .002         -  .001         -  .001         -  .002

101005000   +          0.     + 0.000         + 0.000         + 0.000         + 0.000
            -          0.     - 0.000         - 0.000         - 0.000         - 0.000

101005010   +          0.     + 0.000         + 0.000         + 0.000         + 0.000
            -          0.     - 0.000         - 0.000         - 0.000         - 0.000
101005020   +          0.     + 0.000         + 0.000         + 0.000         + 0.000
            -          0.     - 0.000         - 0.000         - 0.000         - 0.000
101005030   +          0.     + 0.000         + 0.000         + 0.000         + 0.000
            -          0.     - 0.000         - 0.000         - 0.000         - 0.000

101006000   +     410340.     +  .030         +  .000         +  .006         +  .003
            -     322310.     -  .008         -  .000         -  .004         -  .002

101006010   +     367770.     +  .029         +  .000         +  .005         +  .003
            -     321640.     -  .008         -  .000         -  .004         -  .002

101006011   +     183580.     +  .008         +  .000         +  .003         +  .001
            -     183580.     -  .005         -  .000         -  .002         -  .001
```

Table 2-3-b. 1982 EXTERNAL COMBUSTION UNCERTAINTIES (Continued)

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                    EXTERNAL COMBUSTION, BOILER CATEGORY                   PAGE  3
TACR AND EMISSION UNCERTAINTIES PROJECTED TO 1982       RUN DATE= NOV 16,1977
 MODIFIED          TACRF                  EMISSIONS (MILLIONS OF TONS / YEAR)
   SCC          (SCC UNITS)           NOX             HC              CO            PART

101006012   +      185920.        +  .023        +  .000        +  .004        +  .001
            -      185920.        -  .005        -  .000        -  .003        -  .001
101006013   +      183990.        +  .016        +  .000        +  .003        +  .001
            -      183990.        -  .005        -  .000        -  .002        -  .001
101006014   +      182020.        +  .006        +  .000        +  .002        +  .001
            -       36500.        -  .001        -  .000        -  .000        -  .000

101006020   +      182010.        +  .005        +  .000        +  .002        +  .001
            -       20700.        -  .001        -  .000        -  .000        -  .000
101006030   +           0.        + 0.000        + 0.000        + 0.000        + 0.000
            -           0.        - 0.000        - 0.000        - 0.000        - 0.000

101007000   +       15220.        +  .000           NEG            NEG            NEG
            -       15220.        -  .000           NEG            NEG            NEG

101007010   +       15220.        +  .000           NEG            NEG            NEG
            -       15220.        -  .000           NEG            NEG            NEG
101007020            NEG             NEG            NEG            NEG            NEG
                     NEG             NEG            NEG            NEG            NEG
101007030            NEG             NEG            NEG            NEG            NEG
                     NEG             NEG            NEG            NEG            NEG

102002000   +   14393000.        +  .262        +  .021        +  .045        +  .391
            -   14393000.        -  .261        -  .021        -  .034        -  .411

102002010   +    4050200.        +  .043        +  .001        +  .003        +  .049
            -    4050200.        -  .043        -  .001        -  .002        -  .049
102002020   +    4554100.        +  .064        +  .002        +  .007        +  .136
            -    4554100.        -  .064        -  .002        -  .005        -  .135
102002030   +    4558200.        +  .203        +  .002        +  .008        +  .032
            -    4558200.        -  .203        -  .002        -  .005        -  .032
102002040   +    8103300.        +  .096        +  .013        +  .027        +  .216
            -    8103300.        -  .096        -  .013        -  .019        -  .216
102002050   +     860810.        +  .010        +  .001        +  .003        +  .026
            -     860810.        -  .010        -  .001        -  .002        -  .027
102002060   +    3695600.        +  .043        +  .006        +  .012        +  .080
            -    3695600.        -  .043        -  .006        -  .008        -  .088
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Table 2-3-b. 1982 EXTERNAL COMBUSTION UNCERTAINTIES (Continued)

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                        EXTERNAL COMBUSTION, BOILER CATEGORY                  PAGE  4
TACR AND EMISSION UNCERTAINTIES PROJECTED TO 1982        RUN DATE= NOV 16,1977
 MODIFIED          TACRP                   EMISSIONS (MILLIONS OF TONS / YEAR)
   SCC          (SCC UNITS)          NOX              HC              CO            PART

102002070    +     910820.       +  .014        +  .000        +  .001       +  .057
             -     910820.       -  .014        -  .000        -  .001       -  .068
102002080    +          0.       + 0.000        + 0.000        + 0.000       + 0.000
             -          0.       - 0.000        - 0.000        - 0.000       - 0.000
102002090    +    8104900.       +  .097        +  .013        +  .027       +  .267
             -    8104900.       -  .097        -  .013        -  .019       -  .291
102002100    +     962080.       +  .007        +  .003        +  .011       +  .022
             -     962080.       -  .007        -  .003        -  .011       -  .016
102002110    +     405090.       +  .005        +  .001        +  .005       +  .011
             -     405090.       -  .000        -  .001        -  .005       -  .011
102002120    +     455720.       +  .007        +  .000        +  .001       +  .043
             -     455720.       -  .007        -  .000        -  .001       -  .037
102002130    +    1164000.       +  .024        +  .004        +  .013       +  .029
             -    1164000.       -  .017        -  .004        -  .013       -  .025

102004000    +    2416600.       +  .200        +  .015        +  .019       +  .028
             -    2416600.       -  .009        -  .010        -  .017       -  .028

102004010    +    1097700.       +  .132        +  .010        +  .012       +  .013
             -    1097700.       -  .004        -  .007        -  .009       -  .013
102004020    +    1882200.       +  .137        +  .011        +  .014       +  .022
             -    1882200.       -  .007        -  .007        -  .014       -  .022
102004030    +    1045200.       +  .060        +  .005        +  .006       +  .012
             -    1045200.       -  .004        -  .003        -  .004       -  .012

102005000    +     683580.       +  .073        +  .006        +  .007       +  .005
             -     683580.       -  .002        -  .004        -  .005       -  .005

102005010    +     120210.       +  .056        +  .004        +  .005       +  .001
             -     120210.       -  .000        -  .003        -  .004       -  .001
102005020    +     292330.       +  .032        +  .002        +  .003       +  .002
             -     292330.       -  .001        -  .002        -  .002       -  .002
102005030    +     606120.       +  .034        +  .003        +  .003       +  .005
             -     606120.       -  .002        -  .002        -  .003       -  .005

102006000    +     462800.       +  .156        +  .004        +  .022       +  .004
             -     462800.       -  .103        -  .003        -  .015       -  .004
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Table 2-3-b. 1982 EXTERNAL COMBUSTION UNCERTAINTIES (Continued)

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                    EXTERNAL COMBUSTION, BOILER CATEGORY               PAGE  5
TACR AND EMISSION UNCERTAINTIES PROJECTED TO 1982      RUN DATE= NOV 16,1977
 MODIFIED          TACRF                 EMISSIONS (MILLIONS OF TONS / YEAR)
   SCC          (SCC UNITS)        NOX             HC              CO              PART

102006010    +       82764.    +  .113      +  .003      +  .016      +  .001
             -       82764.    -  .073      -  .002      -  .011      -  .001
102006020    +      198640.    +  .094      +  .002      +  .013      +  .002
             -      198640.    -  .062      -  .002      -  .009      -  .002
102006030    +      409730.    +  .052      +  .001      +  .007      +  .004
             -      409730.    -  .038      -  .001      -  .006      -  .004

102007000    +      142990.    +  .000         NEG          NEG          NEG
             -      142990.    -  .000         NEG          NEG          NEG

102007010    +      125700.    +  .000         NEG          NEG          NEG
             -      125700.    -  .000         NEG          NEG          NEG
102007020    +       68100.    +  .000         NEG          NEG          NEG
             -       68100.    -  .000         NEG          NEG          NEG
102007030    +        2800.    +  .000         NEG          NEG          NEG
             -        2800.    -  .000         NEG          NEG          NEG
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SCC 1-01-001-01 through 1-02-999-99 (see Refs. 2-2 and 2-3 for definition of terms and SCC categories). It was necessary to write computer programs to extract, summarize, and check the data contained on this tape. Much of the literature search and literature data analyses were completed by the time the NEDS tape data was received. The NEDS tape data were used as a second data source, both to accomplish a further breakdown of some of the larger source categories into more detailed firing types and to provide a means of estimating the accuracy, or uncertainty, of the data.

In the special case of process gas combustion, the situation was reversed in that little or no data existed in the literature, but the NEDS data indicated large fuel usage rates and NO_x emissions. In that case, only the NEDS tape data were examined in detail, and uncertainties were derived from that data analysis alone. As discussed in Section 2.1, the errors found were sufficiently large to reduce that category to negligible proportions.

The SCC external combustion (boilers) category was subdivided according to the fuels selected for study within this category, which are represented by 58 MSCC categories. In order to accomplish the type of linear projections into the future, with cited uncertainties, as described in Section I, a total of 40 distinct input numbers had to be generated for each MSCC. Thus, for this category alone, more than 2,000 separate data entries had to be considered.

In general, initial efforts were made, from data in the literature, to estimate current values of fuel usage rates and emission factors. The NEDS data were used to improve and confirm these estimates, provide further breakdowns into finer categories, and estimate uncertainties in current data levels. Methods of projecting data into the future could only be derived from the literature and other unpublished data sources. All data sources were also used to estimate uncertainties in the projection methods and the resulting projected levels. The resulting data level estimates and uncertainties were then used to derive the linear slopes and the uncertainties in these slopes.

Since the literature search and analyses of data from the literature provided a major source of current data and the only source of projection data and methods, these data and analyses are discussed in depth in Section 2.4. In most cases, the data finally used in the projections were reviewed and somewhat modified (or established) by subsequent comparison with NEDS tape derived data. A discussion of the NEDS data is contained in Section 2.5.

2.4 DATA ANALYSIS FROM LITERATURE

Data in the literature can be divided into the source categories of utility boilers and industrial boilers. Data concerning these two sources are sufficiently different, both in depth and type, that separate data sources and analyses were necessary to derive the desired data Further, PART control equipment efficiency and degree of application data represented a special effort. Therefore, studies in these three areas were generally conducted separately.

2.4.1 Fuel Usage, NO_x, HC, and CO Emissions in and from Utility Boilers

An Edison Electric Institute (EEI) survey (Ref. 2-4) of several hundred utility steam generator units provided data on boiler firing type, fuel type, and unit megawatt electrical design capacity. This survey provided the basis for a proportional breakdown of burner firing types categorized as follows: tangential, opposed wall, front or back wall, cyclone, and vertical. The sample contained in the EEI survey was sufficiently large to be deemed representative of the overall utility industry.

Since many utility stations were shown to have multifuel operating capability, a further time-related refinement was required. Annual fuel usage statistics for multifuel-fired plants were sampled (Ref. 2-5). The sample size chosen for analysis of these data was arbitrarily limited to utilities with power capability exceeding 400 MW. This was done for reasons of manageability. The average proportions of annual usage of each fuel as reported for these stations (coal/oil, oil/gas, coal/oil/gas) were acquired. In the analysis, data were weighted to account for differences in fuel heating values. The proportional statistics for adjusted fuel consumption and breakdown by firing type were then used to develop a summary breakdown expressed as the percent of total energy output.

The total estimated 1973 electrical energy output of the United States was 1.88×10^{12} kW-hr(Ref. 2-6). The fossil-fueled steam electric energy value of 1.43×10^{12}kW-hr is about 76 percent of the total annual output (Refs. 2-7 and 2-8). An average plant net heating rate of 10,350 Btu/kW-hr was selected as representative of the industry (Refs. 2-9 and 2-10). This equals an electrical conversion efficiency of 33 percent, a figure which is somewhat below the most efficient of recently installed large units but which conservatively accounts for many of the older units still in operation.

With these factors, tables were derived for electrical and heat energy generation by firing type. The heating values for coal, oil, and gas, taken as 25×10^6 Btu/ton, 142,800 Btu/gal, and 1050 Btu/cu ft, respectively, enabled the determination of fuel consumption by firing type.

Emission factors published by the Environmental Protection Agency (EPA) (Ref. 2-11) are given in pounds of pollutants per unit fuel usage and are categorized by source. Additional data on tangential-fired furnace emissions were obtained from other sources (Refs. 2-12 and 2-13). The product of fuel usage multiplied by the appropriate emission factor (CO, HC, NO_x) provided the detailed data breakdown for the stationary power plant emission inventory by boiler firing type.

The emission projections involved establishment of expected fuel usage figures for 1980 (Ref. 2-8). However, current drastic changes in socioeconomic conditions may strongly affect actual overall electric energy demand by 1980 as well as the fuel mix used to supply that demand. The differences between current fuel usage and the 1980 usage estimates represent new construction.

Consideration was given to recent trends showing that Combustion Engineering, supplier of tangential furnaces, has shown increasing market penetration and is currently reported (Ref. 2-14) to be controlling about 50 percent of the new boiler market. In addition, multifuel firing capability, already in common practice, tends to favor a shift in this direction with coal remaining as the predominant fuel, especially in view of uncertainties in the future availability of oil and gas. Thus, the projected fuel usage breakdown, reflecting these considerations, is based on the assumption that one half of the new construction for fuel consumption (coal, oil, and gas) will be allocated to tangential-fired units, and the remaining one half will be proportioned as in 1973. The incremental fuel usage values were summed to the 1973 usages to obtain the projections.

The new construction is expected to fulfill the EPA national emissions requirements already legislated (Ref. 2-15). It is further anticipated that improvements in existing units will be forthcoming. Exploratory efforts concerning the feasibility of reduced NO_x by means of combustion modifications have shown promise in several investigations (Refs. 2-12, 2-16, and 2-17). Therefore, slightly lower emission factors were assumed for NO_x emitted from existing facilities. Other studies which have been conducted in this field are reported in References 2-18 through 2-20.

For all coal-fired furnaces, it was assumed that the 1980 NO_x emission factors could be reduced by 25 percent from the 1973 factors listed in Reference 2-11. NO_x emission factors estimated for coal in 1980 were 13.5 lb/ton for all pulverized firing and 41 lb/ton for cyclone furnaces. The 1973 NO_x emission factors for gas and oil, converted to parts per million (PPM) in the flue gas, are 273 for oil and 238 for gas in tangential-fired boilers and 572 for oil and 476 for gas in other firing types. Recent efforts to reduce NO_x emissions in utility boilers indicate that simple, practical combustion modifications can reduce NO_x emissions in both gas- and oil-fired utility boilers at least to 200 parts per million. On the assumption that this technology is currently available and will be widely implemented by 1980, NO_x emission factors of 36 lb/10^3 gal of oil and 250 lb/10^6 cu ft of gas in all firing types were estimated.

Although there is little well-documented information in the technical literature, the popular media and personal observation of some public and private utilities indicate that natural gas may disappear as a fuel for electric generation well before 1980. Many utilities are already experiencing long seasonal periods during which natural gas fuels are not available. Even the highly publicized Alaskan natural gas supply, when fully developed, is expected to deliver less than 10 percent of the current demand in utility and industrial boilers alone. For these reasons, projected natural gas usage in utility and industrial boilers was estimated to decrease at a slope (and slope uncertainty) which indicates zero usage as early as 1978. Considering the unsubstantiated quality of this type of popular data, however, the uncertainty in this negative slope is large. The projected electrical demand which would have been supplied by natural gas combustion was shifted to coal-burning utilities and coal- and oil-burning industrial boilers.

In general, HC and CO emissions from external combustion boilers are low and usually well below the limits of any foreseen regulations. For this reason, no effort was made to project changes in HC and CO emission factors. In all cases in this category, HC and CO slopes were considered equal to zero.

2.4.2 Fuel Usage, NO_x, HC, and CO Emissions in and from Industrial Boilers

The three major pieces of information needed to calculate the industrial boiler emissions are the installed boiler capacity, the consumption of each type of fuel, and the emission factors. Within the time constraints of this study, only a limited literature search and a survey of potential information sources were possible. For boiler capacity data, the only source located was Reference 2-21, in which were several tables based on information in Reference 2-22. In those tables, industrial boiler capacities were given for 1967, with projections to 1975 and 1980, in terms of total steam generation in pounds per hour An estimate was made of the breakdown of the 1967 total capacity into three size categories: 10 to 100, 100 to 250, and 250 to 500 KPPH.* Sales data from Refs. 2-23 and 2-24 were used to project how the total capacity would be divided into these three size ranges in 1973 and 1980.

The Ehrenfeld 1967 data given in Ref. 2-22 also included coal, oil, and natural gas annual consumption for the industrial boilers. Using heating values for the coal (25 x 10^6 Btu/ton), oil (6 x 10^6 Btu/bbl), and gas (1050 Btu/cu ft) and assuming 1000 Btu/lb heat content of steam, it was possible to relate capacity data in heat output per hour to the annual heat input. A factor of 3800 was derived, an average factor, in hours per year at rated capacity operation. Lacking any later data along these lines, this factor was used for all subsequent year calculations to relate boiler capacities to heat input and thus to total annual fuel consumption.

Next, the total fuel consumption derived for 1973 and 1980 was divided among coal, oil, and gas. The boiler population data in Ref. 2-23 (for 1972) were used to estimate the 1973 fuel usage split. Although these data are boiler number percentages rather than capacity percentages, there are sufficient size categories that the two percentages should not be widely different. For 1980, Battelle is currently working on such an estimate, taking into account the energy supply situation; however, results were not available in time for this study. Therefore, a best estimate was made on the basis that the use of coal would show a sharp rise, both from new boilers and conversion of existing units, with a smaller rise in oil consumption and a decrease in natural gas use. A rough guideline was the fuel breakdown given in Ref. 2-23 for 1950 when coal was widely used in industrial boilers. A further consideration was the greater tendency toward coal in large units compared to the smaller sizes.

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*KPPH = thousands of pounds of steam per hour.

With boiler capacities and fuel consumption estimates in hand, the emissions of NO_x, CO, and HC for 1968 and 1973 were calculated using the emission factors of Ref. 2-11. Emission factors for NO_x from gas-fired boilers, given in Ref. 2-11 for industrial boilers, range from 120 to 230 lb/10^6 cu ft from the smallest to the largest boilers. Rather than trying to interpolate and use multiple factors, an arithmetic average of 175 was applied to the total gas consumption. Since NO_x emissions from natural gas combustion represent only about 20 percent of the total, an error in using an average emission factor should not significantly affect the total emissions.

In estimating probable NO_x emission factors for 1980, it was noted that there are currently no NO_x regulations for industrial boilers other than for new units larger than 250 million Btu/hr heat input but that some sort of control appears likely in the near future. Much of the NO_x control technology developed for utility boilers should be directly applicable, but the larger question concerns the degree to which new regulations will be met in industrial boilers by 1980. For the 1980 projections, it was assumed that the NO_x emission factors for coal firings will be reduced by 25 percent (as in the case of utility boilers) but that NO_x emissions from gas and oil-firings will be reduced by 50 percent, rather than the 58 to 65 percent reduction which appears likely for utility boilers. A summary of the 1973 NO_x emission factors and those assumed in this study for 1980, for both utility and industrial boilers, is as follows:

Fuel	Emission Factor Unit	Use	Utilities 1973	Utilities 1980	Industrial 1973	Industrial 1980
Coal	lb/ton	General	18	13.5	18	13.5
	lb/ton	Cyclone	55	41	55	41
	lb/ton	Stoker	-	-	15	11.25
Oil	lb/1000 gal	Tangential	50	36	40	20
	lb/1000 gal	Other	105	36	80	40
Natural Gas	lb/million cu ft	Tangential	300	250	180	90
	lb/million cu ft	Other	600	250	180	90

As in the utility boiler category, HC and CO emissions were considered currently satisfactory, and the 1980 emissions factor used were unchanged from those of Ref 2-11.

2.4.3 PART Emissions from Utility and Industrial Boilers

The PART emission category is different from those of NO_x, CO, and HC in that PART emissions are not only a function of the fuel type but are also strongly dependent on the PART control equipment used. PART emissions from gas- and oil-fired utility and industrial boilers represent less than seven percent of the total from these sources. As a result, only PART emissions from coal-fired boilers were examined in detail. For these coal-fired boilers, the PART emission factors can be classified in the general pulverized coal category and the more specific firing categories of stoker and cyclone. For each of these categories, the annual PART emissions can be calculated from the product of five factors: (1) coal usage rates, (2) average weight percent of ash in the coal, (3) ash factors, (4) average collector efficiencies, and (5) fraction of total plants using the collectors to control PART emissions. Data for each of these factors were obtained, respectively, from (1) the reference sources and analyses discussed in the previous sections plus Refs. 2-26 through 2-29 in the utility boiler area, (2) Ref. 2-25, (3) Ref. 2-11, (4) Ref. 2-25, and (5) Ref. 2-29 for utility boilers and

Ref. 2-25 for industrial boilers The values of percent ash, ash factors, collector efficiencies and control application factors (2) through (5) used to calculate 1967 to 1973 PART emissions in this analysis were as follows:

Utility Boilers

Boiler Type	Ash Factor[a]	% Ash	Collector Efficiency	Control Application	Net Control
Pulverized	16	11.9	0.92	0.97	0.89
Stoker	13	11.2	0.80	0.87	0.70
Cyclone	3	11.8	0.91	0.79	0.72

Industrial Boilers

Boiler Type	Ash Factor[a]	% Ash	Collector Efficiency	Control Application	Net Control
Pulverized	16	10.6	0.85	0.95	0.81
Stoker	13	10.2	0.85	0.62	0.53
Cyclone	3	10.3	0.82	0.91	0.75

For the utility boiler projections the assumption, based on data in Ref 2-27, was that new construction would be 85 percent of the pulverized category, 15 percent of the cyclone firing type, and no new stoker construction. Application of control equipment to new construction was assumed to be 100 percent.

In the industrial boiler area, EPA standards of performance for new stationary sources (Ref. 2-15) require control efficiencies of about 0.988 (based on allowable emissions of 0.1 lb/million Btu and an average coal ash content of 10.4 percent), but these standards currently apply only to boilers with a capacity greater than 250 million Btu/hr heat input. It was assumed, therefore, that all new construction of boilers greater than 250 million Btu/hr capacity would be 100 percent controlled by the efficiency rate of 0.988. No regulations for industrial boilers of smaller capacity are currently forecast, and the control efficiencies and application (net control) therefore, were assumed to be constant

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[a] The ash factor multiplied by the percent of ash yields the uncontrolled emission factor.

Since PART emissions from gas- and oil-fired boilers, both utility and industrial, together represent a small fraction of those from coal-fired boilers, little effort was made to estimate changes in control efficiencies or control applications. Even on the assumption of 100 percent uncontrolled gas- and oil-fired utility and industrial boilers, the PART emissions projected for gas- and oil-firing represent less than 7 percent of the total from these sources PART emissions from gas- and oil-fired utility boilers were considered uncontrolled in all time periods. Controls for industrial boilers were treated the same except that new construction in the capacity range greater than 250 million Btu/hr were assumed to meet the EPA standards of performance for new stationary sources as given in Ref. 2-15

2.4.4 Update of Charge Rate Data

Emissions from external combustion (boiler) sources, as projected during the first year of the inventory, are quite uncertain. Part of the reason for this uncertainty is the age of the data base (1973 and earlier) but the primary cause is the redistribution of boiler fuel usage among coal, oil and gas fuels resulting from oil and gas shortages. The following paragraphs describe the analysis and rationale used to update the data base for boilers in the charge rate (fuel usage) area. Emission factors were assumed already sufficiently accurate.

2.4.4.1 Utility Boilers

Reference 2-30 lists the annual consumption rate of fossil fuels (coal, oil and gas) used for nationwide electric generation through 1975. This data was used to update the data base for utility boilers firing bituminous coal, residual oil and natural gas. Other utility boiler fuel categories such as distillate oil and process gas contribute insignificant emissions.

The 1975 values for fuel usage rate were distributed among the respective boiler categories in the same proportion as had been observed in the initial (1975) data base. The distribution of fuel usage among three boiler sizes as defined in the initial data base compared favorably with the distribution shown for the same categories in Ref. 2-31. The boiler sizes for which comparisons were made included: (1) less than 10 million BTU per hour, (2) between 10 and 100 million BTU per hour, and (3) greater than 100 million BTU per hour. More than 95 percent of the utility boiler fuel was fired in the 3rd category ($>100 \times 10^6$ BTU/hr), for each of the three fuel types (coal, oil and gas).

Although the 1975 fuel usage data in Reference 2-30 was marked as "preliminary", they are considered quite accurate (<5 percent uncertainty) because little change was observed between preliminary values published in previous years and the revised values published in this (1975) document. Also, good agreement was noticed between Ref. 2-30 data and that published in other independent sources. Therefore, the charge rate uncertainty was set at 3 percent of the nominal value.

The slopes of the charge rates for total coal, oil and gas were set equal to the typical annual growth rates cited in Ref. 2-30 over the last several years. These slopes, for utility boilers, are listed below:

Fuel	Years of Observation	Effective Slope, %
Coal	1970 - 1975	+3.9
Oil	1970 - 1975	+6.0
Natural Gas	1971 - 1975	-10.7

These values for the changes in total fuel charge rates with time were then apportioned among the various utility boiler subcategories in proportion to the subcategory charge rates.

Uncertainties in these slopes, or projections into the future, are, of course, still quite large. This is primarily a result of uncertainties in the shift between fuels which might be implemented in the near future to satisfy the energy demand.

2.4.4.2 Industrial Boilers

Reference 2-31 lists firing rates for several industrial boiler sizes for each of the fuels of interest. Since the installed capacity of industrial boilers is large compared to the new installation/ retirement rates, the relative distribution of usage among boiler sizes and fuel types is expected to be about the same in 1977 as reported in Ref. 2-31 for 1971. Appendix C of Ref. 2-32 describes the growth rates of coal, oil and natural gas usage in industrial applications (based on actual data until 1974 and estimated data for later years). These growth rates are shown below:

	Annual Growth Rates, %		
Fuel	1971-1972	1972-1974	1974-1977
Coal	-1.7	-5.6	+6.3
Oil	+2.3	+2.0	+3.3
Natural Gas	+4.3	+2.3	+2.1

Annual charge rates for 1975 were estimated by projecting the 1971 charge rate data from Ref. 2-31 using the annual growth rates from Ref. 2-32 (the above table). Charge rates calculated in this manner for 1975 were then compared with those previously derived for the same year in this study. Agreement between these two values were excellent for coal usage but differed by 44 and 73 percent for oil and natural gas usage, respectively. Those two estimates were combined to develop new estimates of charge rates and uncertainties for the three fuels for 1975. Charge rates for 1977 and subsequent, then, were projected from the new 1975 levels using the projected annual growth rates from Ref. 2-32.

Although the individual fuel usage rates for industrial boilers may dip or rise drastically during the next few years, the combined firing rate of all three fuels should rise at a relatively constant rate. Although the data in the above table shows that the growth rate for coal usage in industrial boilers ranged from a 5.6 percent decrease in 1973-1974 to a 6.3 percent increase in 1975-1977, the total industrial boiler firing rate growth ranged only from +0.6 percent to +3.3 percent over the same period, with an average of 2.3 percent per year.

2.5 NEDS DATA ANALYSIS

The NEDS data are stored in a large number of SCC by type of source (external combustion boiler, electric generation and industrial), by fuel (e.g., bituminous coal, lignite), and to some degree by firing types (e.g., pulverized wet, cyclone, stoker) (Table A.2 of Ref. 2-3). These data represent a more detailed breakdown than was available in the literature for the boilers of this study. The NEDS data also contain a large amount of detail on primary and secondary PART control equipment, categorized by control equipment identification codes (Table A.3 of Ref. 2-3), which does not appear to be available anywhere else. For these reasons, it was considered desirable to obtain a magnetic tape of data stored in the NEDS system for analysis. The availability of these in-house data on tape allowed extensive computer analysis and represents a powerful tool for emission inventories and other studies. A comparison of some of the totals, such as fuel usage and emissions, with data from other sources indicated that the NEDS data were considerably more comprehensive. In all cases, totals from various sources agreed as well as can be expected with the NEDS data. The NEDS data were initially accumulated and stored over the time period from about 1969 to 1972. Data available from other sources tend to represent time periods from about 1968 to 1973. Comparing the NEDS data with interpolated data for the same time period, and considering the probable accuracies of these other sources, the NEDS data appear to be in good agreement.

Two significant problems with the NEDS tape data were found during this study. Significant errors of unknown origin can exist in some of the stored data. It appears that a single individual can submit data that are grossly in error and this error can enter into and remain in the NEDS data bank, undetected, grossly affecting all summary uses of the data. Annual CO emissions from coal-fired utility boilers were found to be more than a factor of five (more than 3×10^6 tons) too high. Two individuals submitting data in the process gas combustion area may have entered fuel usage data (total of several point sources within their plant) which were too high by factors of as much as 1000 (a total error of more than 2×10^{13} cu ft/yr). Such excessively high values can be detected with relative ease by screening the data for charge rates (fuel usage) larger than that of a very large plant. For excessively small values, however, Aerospace was unable to develop reliable, consistent methods for detecting errors or even to assure that zero values were not valid. The best overall checks found in this study involved correcting excessively high values and comparing the corrected totals against data from other sources, if available. These problems led to rather large estimates of the uncertainty of the final data.

The data stored in the NEDS were generated by many primary sources over a period of several years. In many cases, the emissions recorded were calculated from fuel usage rates and the then-current listing of emission factors. Most of the emission factors used in compiling the NEDS data are listed in the 1972 compilation (Ref. 2-33). From the 1972 compilation to the 1973 compilation (Ref. 2-11), there were some very large changes. Those important to this study are listed below:

Fuel	Plant Type	Emission	Emission Factor Ratio, 1973/1972
Coal	None	-	-
Oil	Utility	CO	75.0
	Industrial	CO	20.0
Natural Gas	Utility	NO_x	1.538
	Utility	HC	0.025
	Utility	CO	42.5
	Industrial	HC	0.075
	Industrial	CO	42.5

The changes in emission factors between these two compilations do not represent real changes in emissions but are more likely errors in the 1972 compilation, the first of its kind ever issued. In some cases, the emissions found in the NEDS tape data analyses could be brought into line with data from other sources by applying the above emission factor corrections. In the case of CO from all fuels, however, the emission totals from the NEDS tape analysis could not be brought into agreement with either the other sources in the literature or the NEDS nationwide emissions reports, even when these corrections were made.

Because of these problems, only the NEDS data which could be roughly verified by some other source were used. Similarly, because of the questions concerning the proper emission factors, the recorded NEDS emission data were not used as such. Instead, the NEDS fuel usage data were multiplied by 1973 emission factors obtained from Ref. 2-11. A check of resulting emission totals calculated in this manner showed reasonably good agreement with direct NEDS emissions data, except as discussed in the CO and the process gas category.

A further complication in using the NEDS point source data (NEDS tape) results from the use of a number of fuels, concurrently or at different times, in the same facility. The emissions, operating times, PART control equipment, and compliance data (card Nos. 3 through 5) are combined, listed, and stored as single values for the facility, while fuel and fuel usage data are listed separately by fuel (multiple cards No. 6). There appears to be no way to determine those emissions or fractions of operating time associated with each fuel. To generate total emissions data from the NEDS tape, this study utilized data from facilities using only one fuel (single card No. 6) to determine an effective emission factor for that SCC. Total emissions for that fuel were then calculated from the total usage of that fuel in that SCC. This procedure assumes that the emission factor for a given fuel in a given facility is the same whether or not the facility operates with multiple fuels. For example, there is some evidence in the literature that NO_x emissions during gas firing may be higher for a significant period of operation if it was preceded by a period of oil firing. No solution for this possible source of error was found.

One of the greatest values of the NEDS tape analysis is in the extremely detailed breakdown of PART control equipment usage and performance. No other source of such detail in the use of PART control equipment was identified. The data on the NEDS tape are such that further valuable information such as collector efficiencies, degree of application, and use of secondary collectors could also be developed. While such data were not of interest to the current study, it appears that a powerful tool for further data analysis is available.

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SECTION III

STATIONARY INTERNAL COMBUSTION ENGINES

3.1 INTRODUCTION

Stationary internal combustion (IC) engines include those used for (1) electrical power generation, (2) industrial use, (3) commercial and institutional application, and (4) engine testing. The fuels used in these engines range from natural gas to crude oil. The types of engines include diesel and spark ignition reciprocating engines and gas turbines.

Since by definition point source engines are those where one or more of the common emissions exceed 100 tons per year, it is to be expected that many stationary engines fall into the area source category (all stationary sources of pollution other than point sources). These engines fail to qualify as point source engines because of (1) a smallness in size, (2) a low usage rate, (3) a low emission factor, or (4) a combination of these factors.

Although the emissions total (point source plus area source) for most types of stationary engines is not much larger than point source only, four engine-fuel combinations were identified where area source emissions are estimated to be significantly large simply because their populations are enormous. These four engines are distillate-fueled and crude-oil-fueled turbines and gasoline-fueled and diesel-fueled reciprocating engines.

This study concentrates on point sources of air pollution as described in Section 3.3; Section 3.4 describes the assessment of the engine categories that make significant contributions to both area and point source emissions.

3.2 SUMMARY

The point source stationary IC engines studied along with their modified source classification code (MSCC) numbers and MSCC charge rate units are listed in Table 3-1. The point source charge rates and emission rates for the two sample years are shown, respectively, in Tables 3-2-a and 3-3-a and their uncertainties in Tables 3-2-b and 3-3-b.

By the 1980's point source IC engines will contribute about one-half million tons per year of both nitrogen oxides (NO_x) and hydrocarbons (HC) and about 60,000 tons of carbon monoxide (CO)annually. The annual area source emissions for the four previously mentioned engines are estimated to be about 3 million tons of NO_x, 1 million tons of HC, and about 13.5 million tons of CO. The largest contributor to stationary IC engine pollution is the conventional gasoline engine.

3.3 POINT SOURCES

This category includes fixed installations of diesel and spark ignition reciprocating engines and gas turbine engines. These engines are used for electrical power generation and for industrial use such as pumps for fuels, water, and sewage and compressors for gaseous fuels and air. The three basic types of engines may be further subdivided into subtypes such as two and four stroke, direct and indirect injection, and carburetion.

However, obtaining emissions from such breakdowns is frustrated by a lack of a breakdown in annual fuel consumption and emission factors by engine subtype. Thus, it is not possible to establish the effect on the environment of variations in engine configuration, state of repair, or specific application. Significant pollution contributors in this category are listed in Table 3-1.

3.3.1 Diesel Engines

Diesel engines are used for electrical generation in oil and gas pipelines, oil and gas exploration, and pumping water and sewage.

(Continued on page 3-10)

Table 3-1. DEFINITION OF INTERNAL COMBUSTION PROCESSES

MSCC	Source Category	Charge Rate Unit
201000000	Internal Combustion (Electrical Generating)	
201001010	Distillate-oil-fueled turbine	1000 gal/yr
201002010	Natural-gas-fueled turbine	Million cu ft/yr
201002020	Natural-gas-fueled reciprocating	Million cu ft/yr
201003010	Diesel-fueled reciprocating	1000 gal/yr
201999970	Other, not classified	Million cu ft/yr
201999980	Other (not classified)	1000 gal/yr
202000000	Internal Combustion (Industrial)	
202001010	Distillate-oil-fueled turbine	1000 gal/yr
202002010	Natural gas turbine	Million cu ft/yr
202002020	Natural gas reciprocating	Million cu ft/yr
202003010	Gasoline reciprocating	1000 gal/yr
202004010	Diesel reciprocating	1000 gal/yr
202999970	Other (not classified)	Million cu ft/yr

Table 3-2-a. 1977 INTERNAL COMBUSTION EMISSIONS AND CHARGE RATES

```
                        INTERNAL COMBUSTION ENGINES                    PAGE  1
ANNUAL CHARGE RATES AND EMISSIONS PROJECTED TO 1977     RUN DATE= NOV 16,1977
 MODIFIED        TACRF             EMISSIONS (MILLIONS OF TONS / YEAR)
   SCC        (SCC UNITS)       NOX            HC            CO          PART

201001000       1163100.        .129          .002          .010          .008

201001010       1163100.        .129          .002          .010          .008

201002000        319570.        .091          .001          .000          .000

201002010        108940.        .019          .001          .000          .000
201002020        210630.        .072         0.000         0.000         0.000

201003000         78259.        .011          .001          .005          .002

201003010         78259.        .011          .001          .005          .002

201999000                       .018          .090          .002          .001

201999970          7590.        .011          .012         0.000         0.000
201999980        125600.        .006          .078          .002          .001

202001000         71473.        .004          .000          .002          .001

202001010         71473.        .004          .000          .002          .001

202002000        914110.        .327          .084          .041          .004

202002010         60868.        .010          .002          .002          .000
202002020        853240.        .318          .081          .039          .004

202003000          3933.        .000          .000          .003          .000

202003010          3933.        .000          .000          .003          .000

202004000         29971.        .005          .000          .002          .000

202004010         29971.        .005          .000          .002          .000

202999000         27466.        .004          .198          .001          .000

202999970         27466.        .004          .198          .001          .000
```

Table 3-2-b. 1977 INTERNAL COMBUSTION UNCERTAINTIES

```
                                   INTERNAL COMBUSTION ENGINES                                    PAGE   1
   TACR AND EMISSION UNCERTAINTIES PROJECTED TO 1977         RUN DATE= NOV 16,1977
   MODIFIED          TACRF                      EMISSIONS (MILLIONS OF TONS / YEAR)
     SCC          (SCC UNITS)         NOX                 HC                  CO                 PART
   201001000    +    3364000.     +  .374        +  .005         +  .030         +  .025
                -    1163100.     -  .129        -  .002         -  .010         -  .008
   201001010    +    3364000.     +  .374        +  .005         +  .030         +  .025
                -    1163100.     -  .129        -  .002         -  .010         -  .008
   201002000    +     418290.     +  .073        +  .002         +  .003         +  .001
                -     113670.     -  .022        -  .001         -  .000         -  .000
   201002010    +     417030.     +  .072        +  .002         +  .003         +  .001
                -     108940.     -  .019        -  .001         -  .000         -  .000
   201002020    +      32461.     +  .011        + 0.000         + 0.000         + 0.000
                -      32461.     -  .011        - 0.000         - 0.000         - 0.000
   201003000    +      16026.     +  .003        +  .000         +  .002         +  .001
                -      16026.     -  .002        -  .000         -  .001         -  .001
   201003010    +      16026.     +  .003        +  .000         +  .002         +  .001
                -      16026.     -  .002        -  .000         -  .001         -  .001
   201999000
                                  +  .004        +  .017         +  .000         +  .001
                                  -  .004        -  .017         -  .000         -  .001
   201999970    +       2302.     +  .003        +  .004         + 0.000         + 0.000
                -       2302.     -  .003        -  .004         - 0.000         - 0.000
   201999980    +      26925.     +  .001        +  .017         +  .000         +  .001
                -      26925.     -  .001        -  .017         -  .000         -  .001
   202001000    +      33032.     +  .002        +  .000         +  .001         +  .000
                -      33032.     -  .002        -  .000         -  .001         -  .000
   202001010    +      33032.     +  .002        +  .000         +  .001         +  .000
                -      33032.     -  .002        -  .000         -  .001         -  .000
   202002000    +     631400.     +  .121        +  .032         +  .024         +  .005
                -     211690.     -  .076        -  .019         -  .010         -  .004
```

Table 3-2-b. 1977 INTERNAL COMBUSTION UNCERTAINTIES (Continued)

INTERNAL COMBUSTION ENGINES

TACR AND EMISSION UNCERTAINTIES PROJECTED TO 1977 RUN DATE= NOV 16,1977

MODIFIED SCC		TACRP (SCC UNITS)		EMISSIONS (MILLIONS OF TONS / YEAR) NOX		HC		CO		PART
202002010	+	597960.	+	.094	+	.025	+	.022	+	.004
	-	60168.	-	.010	-	.002	-	.002	-	.000
202002020	+	202750.	+	.076	+	.021	+	.010	+	.004
	-	202750.	-	.076	-	.019	-	.009	-	.004
202003000	+	1626.	+	.000	+	.000	+	.003	+	.000
	-	1626.	-	.000	-	.000	-	.001	-	.000
202003010	+	1626.	+	.000	+	.000	+	.003	+	.000
	-	1626.	-	.000	-	.000	-	.001	-	.000
202004000	+	26177.	+	.005	+	.000	+	.002	+	.000
	-	26177.	-	.005	-	.000	-	.002	-	.000
202004010	+	26177.	+	.005	+	.000	+	.002	+	.000
	-	26177.	-	.005	-	.000	-	.002	-	.000
202999000	+	9453.	+	.001	+	.207	+	.000	+	.000
	-	9453.	-	.001	-	.068	-	.000	-	.000
202999970	+	9453.	+	.001	+	.207	+	.000	+	.000
	-	9453.	-	.001	-	.068	-	.000	-	.000

Table 3-3-a. 1982 INTERNAL COMBUSTION EMISSIONS AND CHARGE RATES

```
                              INTERNAL COMBUSTION ENGINES                    PAGE   1
  ANNUAL CHARGE RATES AND EMISSIONS PROJECTED TO 1982      RUN DATE= NOV 16,1977
   MODIFIED          TACRF                  EMISSIONS (MILLIONS OF TONS / YEAR)
     SCC          (SCC UNITS)          NOX          HC           CO          PART

  201001000        1350600.          .149         .002         .012         .010

  201001010        1350600.          .149         .002         .012         .010

  201002000         271340.          .077         .000         .000         .000

  201002010          91680.          .016         .000         .000         .000
  201002020         179660.          .061        0.000        0.000        0.000

  201003000          86009.          .012         .001         .006         .002

  201003010          86009.          .012         .001         .006         .002

  201999000                          .020         .107         .002         .002

  201999970           8421.          .013         .014        0.000        0.000
  201999980         150600.          .007         .093         .002         .002

  202001000          85273.          .005         .001         .002         .001

  202001010          85273.          .005         .001         .002         .001

  202002000         764470.          .276         .070         .035         .003

  202002010          39733.          .096         .002         .001         .000
  202002020         724740.          .270         .069         .033         .003

  202003000           5090.          .001         .001         .004         .000

  202003010           5090.          .001         .001         .004         .000

  202004000          39396.          .007         .001         .003         .000

  202004010          39396.          .007         .001         .003         .000

  202999000          36561.          .005         .263         .002         .000

  202999970          36561.          .005         .263         .002         .000
```

Table 3-3-b. 1982 INTERNAL COMBUSTION UNCERTAINTIES

```
                          INTERNAL COMBUSTION ENGINES                   PAGE  1
TACR AND EMISSION UNCERTAINTIES PROJECTED TO 1982       RUN DATE= NOV 16,1977
 MODIFIED         TACRP                 EMISSIONS (MILLIONS OF TONS / YEAR)
   SCC         (SCC UNITS)        NOX            HC            CO          PART

201001000    +    3570500.     +  .398      +  .005      +  .031     +  .026
             -    1350600.     -  .149      -  .002      -  .012     -  .010

201001010    +    3570500.     +  .398      +  .005      +  .031     +  .026
             -    1350600.     -  .149      -  .002      -  .012     -  .010

201002000    +     420910.     +  .074      +  .002      +  .003     +  .001
             -     107630.     -  .025      -  .000      -  .000     -  .000

201002010    +     417120.     +  .072      +  .002      +  .003     +  .001
             -      91680.     -  .016      -  .000      -  .000     -  .000
201002020    +      56380.     +  .019      + 0.000      + 0.000     + 0.000
             -      56380.     -  .019      - 0.000      - 0.000     - 0.000

201003000    +      20738.     +  .003      +  .000      +  .002     +  .001
             -      20738.     -  .003      -  .000      -  .001     -  .001

201003010    +      20738.     +  .003      +  .000      +  .002     +  .001
             -      20738.     -  .003      -  .000      -  .001     -  .001

201999000                      +  .006      +  .032      +  .001     +  .002
                               -  .006      -  .032      -  .001     -  .002

201999970    +       3772.     +  .006      +  .006      + 0.000     + 0.000
             -       3772.     -  .006      -  .006      - 0.000     - 0.000
201999980    +      50990.     +  .003      +  .032      +  .001     +  .002
             -      50990.     -  .003      -  .032      -  .001     -  .002

202001000    +      60420.     +  .003      +  .000      +  .001     +  .001
             -      60420.     -  .003      -  .000      -  .001     -  .001

202001010    +      60420.     +  .003      +  .000      +  .001     +  .001
             -      60420.     -  .003      -  .000      -  .001     -  .001

202002000    +     687910.     +  .153      +  .040      +  .027     +  .005
             -     322170.     -  .119      -  .030      -  .015     -  .003
```

Table 3-3-b. 1982 INTERNAL COMBUSTION UNCERTAINTIES (Continued)

```
                              INTERNAL COMBUSTION ENGINES                                  PAGE  2
  TACR AND EMISSION UNCERTAINTIES PROJECTED TO 1982          RUN DATE= NOV 16,1977
   MODIFIED          TACRF                     EMISSIONS (MILLIONS OF TONS / YEAR)
     SCC          (SCC UNITS)           NOX              HC               CO               PART

  202002010    +      608840.        +  .096        +  .025        +  .023        +  .004
               -       39733.        -  .006        -  .002        -  .001        -  .000
  202002020    +      320210.        +  .119        +  .031        +  .015        +  .003
               -      320210.        -  .119        -  .030        -  .015        -  .003

  202003000    +        2769.        +  .000        +  .000        +  .004        +  .000
               -        2769.        -  .000        -  .000        -  .002        -  .000

  202003010    +        2769.        +  .000        +  .000        +  .004        +  .000
               -        2769.        -  .000        -  .000        -  .002        -  .000

  202004000    +       26695.        +  .005        +  .000        +  .002        +  .000
               -       26695.        -  .005        -  .000        -  .002        -  .000

  202004010    +       26695.        +  .005        +  .000        +  .002        +  .000
               -       26695.        -  .005        -  .000        -  .002        -  .000

  202999000    +       18461.        +  .003        +  .292        +  .001        +  .000
               -       18461.        -  .003        -  .133        -  .001        -  .000

  202999970    +       18461.        +  .003        +  .292        +  .001        +  .000
               -       18461.        -  .003        -  .133        -  .001        -  .000
```

For electrical generation, diesel engines represent on the order of 1.2 percent of the 1970 total electrical generating capacity in the United States and only about 0.3 percent of the total power generated, for an average utilization of about 12 percent. These engines are used for electrical peaking power and also standby installation. The projected utilization factor for 1980 drops to eight percent.

Diesel engines represent about four percent of the installed horsepower in pipelines and about five percent of the power generated. For oil and gas exploration, about 75 percent of the power used is generated by diesel engines. For municipal water and sewage pumping about 50 percent is diesel-powered, while agricultural water pumping is done almost exclusively by diesel engines.

3.3.2 Gas Turbines

The main applications for stationary gas turbines include electric power generation for utilities and for industrial and pipeline use. Gas turbines have low initial costs, short delivery times, small space requirements, flexible fuel needs, and high thermal efficiency. For these reasons, turbines are being installed in electrical plants to replace steam plants or to add capacity.

Gas turbine engines vary greatly in size and configuration. Turbines have single- or two-shaft designs. Both types can be operated in simple cycles, regenerative cycles, or combined cycles. The simple-cycle engines operate at 25 [illegible] percent efficiency. Regenerative cycles utilize a heat exchanger which uses turbine exhaust gases to heat the air as it passes from the compressor into the combustor. Efficiency of these engines runs about 34 to 38 percent. In the combined cycle, turbine exhaust gas is used to generate steam which drives a second generator or other device. Efficiencies of 40 to 42 percent are realized with these units.

3.3.3 Spark Ignition Engines

The spark ignition internal combustion engine is the most widely used powerplant in the world today. These engines range from small single-cylinder units producing as little as a fraction of a horsepower to large multicylinder units with power ratings of several thousand horsepower. The large units are predominantly used in stationary power applications.

Medium-sized gasoline engines (50 to 200 hp) are used for commercial and construction site compressors, pumps, blowers, and electric power generators. Medium-large spark ignition engines (200 to 1000 hp) are generally operated on gaseous fuels to power gas compressors or standby power generators. Large spark ignition engines (greater than 1000 hp) always operate on gaseous fuels and are used for gas-well recompression, gas plant compressors, refinery process compressors, water and sewage pumping, and continuous electrical power generation.

3.3.4 Charge Rate

The NEDS was used as the primary source of data. Annual charge rates (fuel consumption), as of the year of record, formed the starting point for the charge rate projections.

The rate of change of charge rate for electric utility turbines is based on the fuel demand data shown in Figure 3-1. The total rises every year for all fuels except natural gas, reflecting the increased dependence on turbine power. Lacking fuel consumption projections on gas turbines for industrial use, the assumption was made that charge rate trends for these turbines are equal to those for electrical power demand. For turbines used in the handling of petroleum products in such services as pumping and pressurization, it is also reasonable to assume that the same trends exist as for the electric utility consumers.

For reciprocating engines, it was necessary to use less direct methods of estimating charge rate changes. Table 3-4 shows data on the number of IC engines versus end use for gasoline and diesel fuels. Only those listed in the source (Ref. 3-4) for construction, generator sets, or general industrial use were considered in this part of the study. Of the engines produced (Table 3-4), many were probably for replacement of

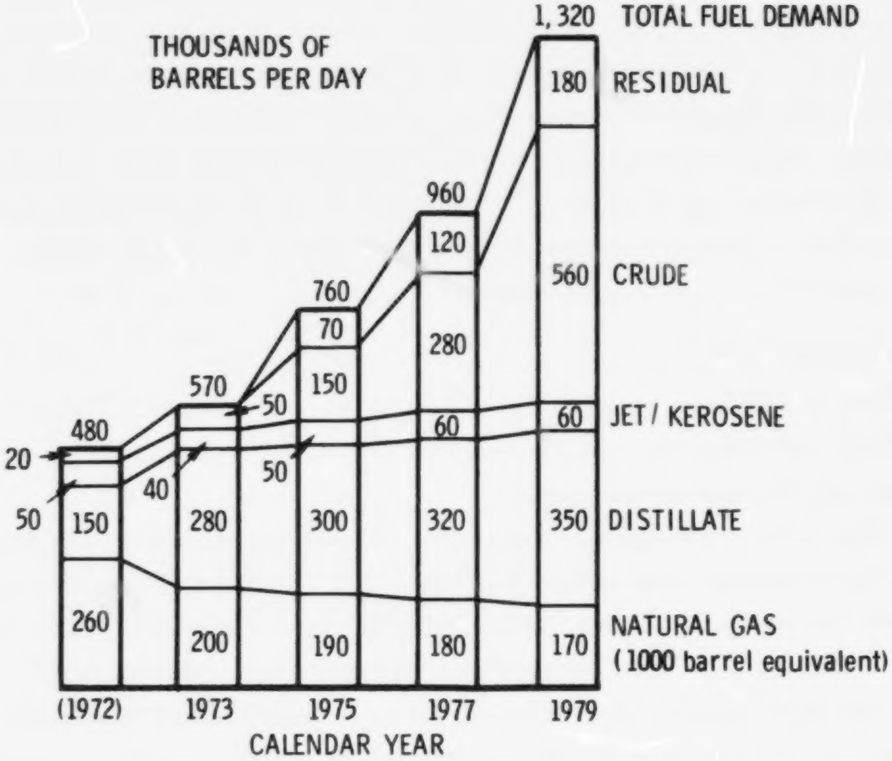

Figure 3-1. Electric utility gas turbine fuel demand

Table 3-4. INTERNAL COMBUSTION ENGINE DISTRIBUTION: NUMBER VERSUS END USE

Engine Type and End Use[a]	Number of IC Engines Distributed[b]									
	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974
Gasoline										
Construction and General Industrial Use	1,172,836	1,306,153	1,192,112	1,239,276	1,424,790	1,225,742	1,174,173	975,637	1,399,800	1,272,551
Generator Sets	67,769	76,678	67,930	67,798	90,760	86,264	104,142	146,270	165,183	176,014
Total Gasoline	1,240,605	1,382,831	1,260,042	1,307,074	1,515,550	1,312,006	1,278,320	1,121,907	1,564,983	1,448,565
Diesel										
Construction and General Industrial Use	130,185	140,021	134,665	139,577	156,329	142,266	130,216	150,823	175,071	200,054
Generator Sets	13,209	12,746	5,564	6,070	8,535	10,201	8,400	9,661	13,327	15,212
Total Diesel	143,394	152,767	140,299	145,647	164,864	152,467	138,616	160,484	188,398	215,266
Total IC Engines	1,383,999	1,535,598	1,400,271	1,452,721	1,680,414	1,464,473	1,416,936	1,282,991	1,753,381	1,663,831

[a] Ref. 3-4.

[b] Represents total number of engines shipped or produced and incorporated into products at the same establishment during the time period 1965 through 1974.

worn-out engines or were exported, with perhaps only 10 percent of production going into new installations. Hence, the assumption of a change of charge rate based on 10 percent of the annual production seems conservative, but the uncertainty of this slope is rather large. Comparison of several sources of predicted consumption for electrical generation shows variations in slopes of from 3 to 22 percent per year. Thus, a 10 percent slope with 10 percent uncertainty in the slope was assumed.

3.3.5 Emission Factors

The emission factors were derived from the NEDS data by dividing the emissions by the charge rate. Other sources of emission factors (Refs. 3-1 through 3-3) were used to determine the uncertainty of the NEDS data. It was assumed that emission factors would not change with the passage of time. The only factor that would change that assumption would be the imposition of clean air standards on all of the users of this equipment. This factor was ignored in the data input; thus, the data represent emissions with no controls imposed.

3.3.6 Results

Table 1-6-a shows the 1982 projections of annual charge rates and emissions for point sources. The data show that about one-half million tons per year of both NO_x and HC are produced by stationary IC engines. Of this amount, about 50 percent of the NO_x and 25 percent of the HC are from electrical generating plants, with the remainder from industrial sources. In the electrical generating category, the worst offender is the distillate-oil-fueled turbine (201001010). With a charge rate of over 1.35 billion gal/year, it contributes about 150,000 tons/year of NO_x. In the industrial use classification, natural gas reciprocating engines (202002020) contribute about 270,000 tons/year of NO_x from about 725 billion cu ft/year of gas.

3.4 TOTAL EMISSIONS FROM SELECTED STATIONARY IC ENGINES (POINT AND AREA SOURCES)

3.4.1 Introduction

As reported in Section 3.1, four stationary IC engine-fuel combinations were identified whose total (area plus point source) emissions far exceed the estimated point source emissions reported in Section 3.3. The four offenders are distillate-fueled and crude-oil-fueled turbines, and gasoline-fueled and diesel-fueled reciprocating engines. Identification of the engine types responsible for these large area source emissions was possible through analysis of the data extracted from Refs. 3-1, 3-4, and 3-5. This section reports the rationale and results of estimating the total emissions for those four types of engines.

3.4.2 Summary

Four engine-fuel combinations were found to contribute potentially significant amounts of area source pollution: distillate-fueled and crude-oil-fueled turbines and gasoline-based and diesel-fueled reciprocating engines. Table 3-5 shows the total emissions for these engines in 1980. Table 3-6 gives the 1980 projection of pollutants from these four sources in excess of the point sources data reported in Section 3.3.

3.4.3 Discussion

3.4.3.1 Turbines

In 1971, the installed horsepower for gas turbines was about 38 million. About 29 million of that was for electrical power generation, and the remainder was for pipelines and natural gas processing. For power generation, gas turbines provide the repowering when old and less efficient plants are retired and also fill the need for increased power. In 1970, approximately 5 percent of the power generated was by gas turbines; by 1980, it is estimated that as much as 12 percent of the power capacity will be from gas turbines. Projected electrical generation use is about 120-million hp in

Table 3-5. 1980 PROJECTION OF TOTAL INTERNAL COMBUSTION ENGINE EMISSIONS[a]

Source Category	Emissions, million tons/yr			Charge Rate, 1000 gal/yr
	NO_x	HC	CO	
Distillate-Fueled Turbines	0.459	0.011	0.060	6.70×10^6
Crude-Oil-Fueled Turbines	0.884	0.022	0.116	12.90×10^6
Gasoline-Fueled Reciprocating Engines	1.345	0.924	13,273	12.75×10^6
Diesel-Fueled Reciprocating Engines	0.432	0.032	0.142	2.40×10^6
Total	3.120	0.989	13.591	34.75×10^6

[a] Point source and area source emissions.

Table 3-6. 1980 PROJECTION OF AREA SOURCE INTERNAL COMBUSTION ENGINE EMISSIONS

Source Category	Emissions, million tons/yr			Charge Rate, 1000 gal/yr
	NO_x	HC	CO	
Distillate-Fueled Turbines	0.313	0.009	0.047	5.34×10^6
Crude-Oil-Fueled Turbines	0.884	0.022	0.116	12.90×10^6
Gasoline-Fueled Reciprocating Engines	1.344	0.923	13.269	12.74×10^6
Diesel-Fueled Reciprocating Engines	0.414	0.031	0.134	2.28×10^6
Total	2.955	0.985	13.566	33.26×10^6

1980. Similar growth rates for other uses can be expected. By 1980, therefore, total gas turbine installed horsepower will be on the order of 150 million.

Figure 3-1 shows distillate consumption for gas turbines for electrical generation growing to 350,000 bbl (14.7-million gal/day in 1979). Projecting this to 1980, fuel consumption can be expected to be 5.6-billion gal/year for electrical generation alone. Adding consumption for other uses increases this number by 20 percent to 6.7-billion gal/year. The 1979 crude oil demand from Figure 3-1 is 560,000 bbl (23.52-million gal/day). Projecting the growth rate to 1980 and adding 20 percent for uses other than electrical generation, the estimated consumption of crude oil in gas turbines will be 12.9-billion gal/year in 1980.

Emission factors used to estimate total emissions are the average of emission factors derived from the NEDS data and from Refs. 3-1 through 3-3. Crude oil emission factors were assumed to be the same as the distillate emission factors, in the absence of any other information.

3.4.3.2 Diesel Engines

In Ref. 3-1, the total estimated installed horsepower of stationary diesel engines was about 16-million bhp (brake horsepower) in 1971. Of this total, 5.2-million bhp were used for electrical generation, and the remainder was for industrial uses.

Table 3-4 indicates that about 215,000 diesel engines for industrial construction and generator sets were shipped in 1974. Total horsepower was about 42 million for engines of greater than 50 hp. To estimate fuel consumption, it was necessary to make the following assumptions:

a. Twenty percent of the engines shipped were new installations. The remainder were replacement engines or were exported (nine percent were exported in 1974).

b. Engines will be operated on an average of 1170 hr/year. NEDS data for 1970 indicate an average of 1888 hr/year for electrical generation and 5282 hr/year for industrial use. The estimated 1980 operation is 8 percent for electrical generation and 15 percent for industrial use.

c. Specific fuel consumption is 0.40 lb/bhp-hr. (According to Ref. 3-1, an average specific fuel consumption is 0.403 for diesels of this class.) Using data from Ref. 3-4 and the 1974 growth rate, it is estimated that diesel horsepower will be about 36 million in 1980; fuel consumption will be 2.40-billion gal/year (7.0 lb/gal). Emission factors were derived as for gas turbines (Section 3.3.5).

3.4.3.3 Spark Ignition Engines

Spark ignition engines, both liquid- and gaseous-fueled, are by two orders of magnitude the most common engines in the country today. The 1971 total installed horsepower is estimated at 800-million (Ref. 3-1). These engines are used for everything from small power tools to 1000-hp and greater compressors, pumps, and electrical power installations.

Table 3-4 shows the number of IC engines shipped in the years 1965 to 1974. Gasoline engines for construction, general industrial use, and electrical generator sets number well over one million in each of those years. Assuming that the engines in these categories are the larger horsepower rated engines, this represents about 50-million hp/year. Of the 800-million hp in 1971, it is estimated that about 50 percent was devoted to these categories.

Using the same assumptions as were made for diesel engines, namely, that 20 percent were new installations, but now assuming the average engine is used for 300 hr/year, the 1980 estimated installed horsepower is 490 million and the annual fuel consumption (at 0.52 lb/bhp-hr) is 12.75-billion-gal/year. Gasoline density of 6.0 lb/gal was used in this computation.

Emission factors were derived by the same method used for gas turbines (Section 3.3.5).

3.4.3.4 Results and Conclusions

From charge rates and emission factors, the 1980 total emissions were estimated and are presented in Table 3-5. The data indicate that about 3-million tons of NO_x, 1-million tons of HC, and 13.6-million tons of CO (mainly from gasoline engines) will be emitted from these engines. Table 3-6 is the same data minus the point source data. This shows an estimate of the area source pollution.

The uncertainty of the data is large. Although the assumptions made are thought to be conservative, the real contribution of these engines could be much higher.

The conclusions to be drawn from this study are that a large number of stationary IC engines are being produced in this country every year and that information as to the application and utilization rates of these engines is lacking. Therefore, a potentially large source of air pollution is going undetected. Efforts to trace these engines to the user and to estimate numbers of engines, use rate, and emissions are recommended.

3.5 REFERENCES

3-1. W. U. Roessler, et al., Assessment of the Applicability of Automotive Emission Control Technology to Stationary Engines, EPA-650/2-74-051, The Aerospace Corporation, El Segundo, California (July 1974).

3-2. C. R. McGowin, Stationary Internal Combustion Engines in the United States, EPA-R2-73-210, Shell Development Company, Houston, Texas (April 1973).

3-3. NEDS Source Classification Codes and Emission Factor Listing (SCC Listing), Office of Air and Waste Material, Office of Air Quality Planning and Standards, U.S. Environmental Protection Agency, Washington, D.C. (July 1974).

3-4. "Internal Combustion Engines: 1965 through 1974," Current Industrial Reports Series, MA-35L (65 through 74)-1, U.S. Bureau of the Census, Washington, D.C. (1975).

3-5. V. DeBiasi, "Double Standard on Fuel Oils Would Favor Steam over Gas Turbine Plants," Gas Turbine World (September 1973).

SECTION IV

CHEMICAL MANUFACTURING

4.1 INTRODUCTION

The emission sources discussed in this section are classified under the general process category of chemical manufacturing and the more specific categories of carbon black and ammonia manufacturing. The emissions under consideration are oxides of nitrogen (NO_x), hydrocarbons (HC), carbon monoxide (CO), and particulate (PART) matter.

This section describes the development of the data base used to calculate emissions from chemical manufacturing. The development of emission equations is described in Section I, Data Handling. Chemical manufacturing processes studies are defined according to the National Emissions Data System (NEDS) Source Classification Code (SCC) and, in Table 4-1, by the NEDS Modified Source Classification Code (MSCC) developed by The Aerospace Corporation for this study.

4.2 SUMMARY

Chemical manufacturing production rates and emissions are defined for two sample years and are listed in Tables 4-2-a and 4-3-a with the respective uncertainties in the production and emission data listed in Tables 4-2-b and 4-3-b. Table 4-1 describes the process and production rate (charge rate) unit for each MSCC for which emissions were determined.

(Continued on page 4-9)

Table 4-1. DEFINITION OF CHEMICAL MANUFACTURING PROCESSES

MSCC	Source Category	Charge Rate Unit
301002010	Purge gas in ammonia plant with methanator	Tons/yr
301002020	Storage and loading in ammonia plant with methanator	
301003010	Regenerator exit in ammonia plant with CO absorber	
301003020	Purge gas in ammonia plant with CO absorber	
301003030	Storage and loading in ammonia plant with CO absorber	
301003990	Miscellaneous processes in ammonia plant with CO absorber	
301005010	Channel process carbon black production	
301005020	Thermal processes carbon black production	
301005030	Gas-fired furnace process carbon black production	
301005040	Oil-fired furnace process carbon black production	
301005050	Gas- and oil-fired furnace process carbon black production	
301005991	SIC 2952 sector of miscellaneous carbon black processes	
301005992	SIC 3624 sector of miscellaneous carbon black processes	
301005993	SIC 3999 sector of miscellaneous carbon black processes	
301005994	SIC 2899 sector of miscellaneous carbon black processes	
301005995	All other SICs of sector of miscellaneous carbon black processes	
301999991	SIC 2818 sector of miscellaneous chemical manufacturing	
301999992	SIC 3999 sector of miscellaneous chemical manufacturing	
301999993	All other SICs of sector of miscellaneous chemical manufacturing	

[a] Standard industrial classification (SIC). The product description corresponding to each SIC is given in Ref. 4-1.

Table 4-2-a. 1977 CHEMICAL MANUFACTURING EMISSIONS AND CHARGE RATES

INDUSTRIAL PROCESS, CHEMICAL MANUFACTURING PAGE 1

ANNUAL CHARGE RATES AND EMISSIONS PROJECTED TO 1977 RUN DATE= NOV 16,1977

MODIFIED SCC	TACRF (SCC UNITS)	EMISSIONS (MILLIONS OF TONS / YEAR) NOX	HC	CO	PART
301002000	6496800.	NEG	.223	.003	NEG
301002010	5570200.	NEG	.223	.003	NEG
301002020	926600.	NEG	0.000	0.000	NEG
301003000	2598800.	NEG	.033	.049	NEG
301003010	818200.	NEG	.001	.049	NEG
301003020	790400.	NEG	.032	0.000	NEG
301003030	590400.	NEG	0.000	0.000	NEG
301003990	399800.	NEG	.000	0.000	NEG
301005000	6119400.	NEG	.324	2.292	NEG
301005010	118400.	NEG	.105	.475	NEG
301005020	231680.	NEG	.000	.003	NEG
301005030	33398.	NEG	.029	.088	NEG
301005040	516080.	NEG	.108	.579	NEG
301005050	673300.	NEG	.074	1.092	NEG
301005990	4546600.	NEG	.009	.055	NEG
301005991	4003000.	NEG	0.000	0.000	NEG
301005992	425400.	NEG	.004	.009	NEG
301005993	24330.	NEG	.005	.045	NEG
301005994	44550.	NEG	.000	.000	NEG
301005995	49290.	NEG	0.000	0.000	NEG
301999000	151180000.	NEG	.518	.336	NEG
301999990	151180000.	NEG	.518	.336	NEG
301999991	70000000.	NEG	.276	.067	NEG
301999992	181500.	NEG	.018	.153	NEG
301999993	81000000.	NEG	.224	.116	NEG

Table 4-2-b. 1977 CHEMICAL MANUFACTURING UNCERTAINTIES

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                   INDUSTRIAL PROCESS, CHEMICAL MANUFACTURING              PAGE  1
TACR AND EMISSION UNCERTAINTIES PROJECTED TO 1977       RUN DATE= NOV 16,1977
 MODIFIED        TACRF                    EMISSIONS (MILLIONS OF TONS / YEAR)
   SCC        (SCC UNITS)            NOX             HC              CO            PART
301002000   +     239590.            NEG        +  .029        +  .001             NEG
            -     239590.            NEG        -  .029        -  .001             NEG

301002010   +     236350.            NEG        +  .029        +  .001             NEG
            -     236350.            NEG        -  .029        -  .001             NEG
301002020   +      39290.            NEG        + 0.000        + 0.000             NEG
            -      39290.            NEG        - 0.000        - 0.000             NEG

301003000   +      56997.            NEG        +  .004        +  .033             NEG
            -      56997.            NEG        -  .004        -  .033             NEG

301003010   +      34731.            NEG        +  .000        +  .033             NEG
            -      34731.            NEG        -  .000        -  .033             NEG
301003020   +      33543.            NEG        +  .004        + 0.000             NEG
            -      33543.            NEG        -  .004        - 0.000             NEG
301003030   +      25076.            NEG        + 0.000        + 0.000             NEG
            -      25076.            NEG        - 0.000        - 0.000             NEG
301003990   +      16982.            NEG        +  .000        + 0.000             NEG
            -      16982.            NEG        -  .000        - 0.000             NEG

301005000   +     228300.            NEG        +  .074        +  .353             NEG
            -     228300.            NEG        -  .074        -  .352             NEG

301005010   +      82790.            NEG        +  .073        +  .333             NEG
            -      82790.            NEG        -  .073        -  .333             NEG
301005020   +      18202.            NEG        +  .000        +  .000             NEG
            -      18202.            NEG        -  .000        -  .000             NEG
301005030   +       2640.            NEG        +  .003        +  .007             NEG
            -       2640.            NEG        -  .003        -  .007             NEG
301005040   +      40800.            NEG        +  .010        +  .054             NEG
            -      40800.            NEG        -  .010        -  .053             NEG
301005050   +      53227.            NEG        +  .007        +  .102             NEG
            -      53227.            NEG        -  .006        -  .102             NEG
301005990   +     201070.            NEG        +  .001        +  .005             NEG
            -     201070.            NEG        -  .001        -  .005             NEG

301005991   +     200000.            NEG        + 0.000        + 0.000             NEG
            -     200000.            NEG        - 0.000        - 0.000             NEG
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Table 4-2-b. 1977 CHEMICAL MANUFACTURING UNCERTAINTIES (Continued)

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              INDUSTRIAL PROCESS, CHEMICAL MANUFACTURING              PAGE  2
TACR AND EMISSION UNCERTAINTIES PROJECTED TO 1977         RUN DATE= NOV 16,1977
 MODIFIED           TACRF                 EMISSIONS (MILLIONS OF TONS / YEAR)
   SCC           (SCC UNITS)         NOX             HC              CO          PART

301005992    +       20000.          NEG       +   .000       +   .001           NEG
             -       20000.          NEG       -   .000       -   .001           NEG
301005993    +        1000.          NEG       +   .001       +   .005           NEG
             -        1000.          NEG       -   .001       -   .005           NEG
301005994    +        2000.          NEG       +   .000       +   .000           NEG
             -        2000.          NEG       -   .000       -   .000           NEG
301005995    +        5000.          NEG       +  0.000       +  0.000           NEG
             -        5000.          NEG       -  0.000       -  0.000           NEG

301999000    +    17464000.          NEG       +   .065       +   .129           NEG
             -    17464000.          NEG       -   .065       -   .129           NEG

301999990    +    17464000.          NEG       +   .065       +   .129           NEG
             -    17464000.          NEG       -   .065       -   .129           NEG

301999991    +     7000000.          NEG       +   .039       +   .010           NEG
             -     7000000.          NEG       -   .039       -   .010           NEG
301999992    +       20000.          NEG       +   .011       +   .126           NEG
             -       20000.          NEG       -   .011       -   .126           NEG
301999993    +    16000000.          NEG       +   .050       +   .026           NEG
             -    16000000.          NEG       -   .050       -   .026           NEG
```

Table 4-3-a. 1982 CHEMICAL MANUFACTURING EMISSIONS AND CHARGE RATES

INDUSTRIAL PROCESS, CHEMICAL MANUFACTURING PAGE 1

ANNUAL CHARGE RATES AND EMISSIONS PROJECTED TO 1982 RUN DATE= NOV 16,1977

MODIFIED SCC	TACRF (SCC UNITS)	EMISSIONS (MILLIONS OF TONS / YEAR) NOX	HC	CO	PART
301002000	7473800.	NEG	.256	.003	NEG
301002010	6408200.	NEG	.256	.003	NEG
301002020	1065600.	NEG	0.000	0.000	NEG
301003000	2988300.	NEG	.038	.056	NEG
301003010	941200.	NEG	.001	.056	NEG
301003020	908900.	NEG	.036	0.000	NEG
301003030	678900.	NEG	0.000	0.000	NEG
301003990	459300.	NEG	.000	0.000	NEG
301005000	6282100.	NEG	.331	2.420	NEG
301005010	97664.	NEG	.086	.392	NEG
301005020	268890.	NEG	.000	.004	NEG
301005030	37393.	NEG	.032	.098	NEG
301005040	577780.	NEG	.121	.649	NEG
301005050	753800.	NEG	.083	1.223	NEG
301005990	4546600.	NEG	.009	.055	NEG
301005991	4003000.	NEG	0.000	0.000	NEG
301005992	425400.	NEG	.004	.009	NEG
301005993	24330.	NEG	.005	.045	NEG
301005994	44550.	NEG	.000	.000	NEG
301005995	49290.	NEG	0.000	0.000	NEG
301999000	151180000.	NEG	.518	.336	NEG
301999990	151180000.	NEG	.518	.336	NEG
301999991	70000000.	NEG	.276	.067	NEG
301999992	181500.	NEG	.018	.153	NEG
301999993	81000000.	NEG	.224	.116	NEG

Table 4-3-b. 1982 CHEMICAL MANUFACTURING UNCERTAINTIES

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                    INDUSTRIAL PROCESS, CHEMICAL MANUFACTURING              PAGE  1
TACR AND EMISSION UNCERTAINTIES PROJECTED TO 1982        RUN DATE= NOV 16,1977
 MODIFIED            TACRF               EMISSIONS (MILLIONS OF TONS / YEAR)
   SCC            (SCC UNITS)         NOX              HC              CO            PART

301002000    +      335720.           NEG        +   .035       +   .001            NEG
             -      335720.           NEG        -   .035       -   .001            NEG

301002010    +      331210.           NEG        +   .035       +   .001            NEG
             -      331210.           NEG        -   .035       -   .001            NEG
301002020    +       54824.           NEG        + 0.000        + 0.000             NEG
             -       54824.           NEG        - 0.000        - 0.000             NEG

301003000    +       79980.           NEG        +   .005       +   .038            NEG
             -       79980.           NEG        -   .005       -   .038            NEG

301003010    +       48751.           NEG        +   .000       +   .038            NEG
             -       48751.           NEG        -   .000       -   .038            NEG
301003020    +       46963.           NEG        +   .005       + 0.000             NEG
             -       46963.           NEG        -   .005       - 0.000             NEG
301003030    +       35283.           NEG        + 0.000        + 0.000             NEG
             -       35283.           NEG        - 0.000        - 0.000             NEG
301003990    +       23867.           NEG        +   .000       + 0.000             NEG
             -       23867.           NEG        -   .000       - 0.000             NEG

301005000    +      247220.           NEG        +   .099       +   .469            NEG
             -      241630.           NEG        -   .088       -   .418            NEG

301005010    +      110770.           NEG        +   .098       +   .445            NEG
             -       97664.           NEG        -   .086       -   .392            NEG
301005020    +       22236.           NEG        +   .000       +   .000            NEG
             -       22236.           NEG        -   .000       -   .000            NEG
301005030    +        3497.           NEG        +   .003       +   .009            NEG
             -        3497.           NEG        -   .003       -   .009            NEG
301005040    +       54118.           NEG        +   .012       +   .069            NEG
             -       54118.           NEG        -   .012       -   .068            NEG
301005050    +       70594.           NEG        +   .009       +   .130            NEG
             -       70594.           NEG        -   .008       -   .130            NEG
301005990    +      201070.           NEG        +   .001       +   .005            NEG
             -      201070.           NEG        -   .001       -   .005            NEG

301005991    +      200000.           NEG        + 0.000        + 0.000             NEG
             -      200000.           NEG        - 0.000        - 0.000             NEG
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Table 4-3-b. 1982 CHEMICAL MANUFACTURING UNCERTAINTIES (Continued)

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                 INDUSTRIAL PROCESS, CHEMICAL MANUFACTURING           PAGE  2
TACR AND EMISSION UNCERTAINTIES PROJECTED TO 1982         RUN DATE= NOV 16,1977
 MODIFIED          TACRF             EMISSIONS (MILLIONS OF TONS / YEAR)
   SCC          (SCC UNITS)        NOX            HC              CO           PART

301005992   +      20000.          NEG        +  .000         +  .001          NEG
            -      20000.          NEG        -  .000         -  .001          NEG
301005993   +       1000.          NEG        +  .001         +  .005          NEG
            -       1000.          NEG        -  .001         -  .005          NEG
301005994   +       2000.          NEG        +  .000         +  .000          NEG
            -       2000.          NEG        -  .000         -  .000          NEG
301005995   +       5000.          NEG        + 0.000         + 0.000          NEG
            -       5000.          NEG        - 0.000         - 0.000          NEG

301999000   +   17464000.          NEG        +  .065         +  .129          NEG
            -   17464000.          NEG        -  .065         -  .129          NEG

301999990   +   17464000.          NEG        +  .065         +  .129          NEG
            -   17464000.          NEG        -  .065         -  .129          NEG

301999991   +    7000000.          NEG        +  .039         +  .010          NEG
            -    7000000.          NEG        -  .039         -  .010          NEG
301999992   +      20000.          NEG        +  .011         +  .126          NEG
            -      20000.          NEG        -  .011         -  .126          NEG
301999993   +   16000000.          NEG        +  .050         +  .026          NEG
            -   16000000.          NEG        -  .050         -  .026          NEG
```

4.3 EMISSION ANALYSIS

The NEDS categorizes chemical manufacturing as a member of the industrial process family of stationary sources of emissions (Ref. 4-2). Industrial process emissions are compared to other point sources in Table 4-4. Industrial process emissions for chemical manufacturing (SCC 3-01-xxx-xx) are compared in Table 4-5 with emissions from the petroleum industry and other members of the industrial process group. The PART and NO_x emissions from chemical manufacturing represent a small fraction, approximately three percent and four percent, respectively, of total industrial process emissions. Since the PART and NO_x emissions from chemical manufacturing processes represent such small fractions of the totals from stationary sources, these pollutants were largely neglected in this study.

The charge rate, emissions, and other pertinent data were extracted from the NEDS point source data for each of the 143 SCC process categories in the chemical manufacturing group. Table 4-6 ranks the categories with the highest charge rates. Tables 4-7 and 4-8, respectively, list the most significant chemical manufacturing emitters by SCC category and product for HC and CO emissions. In comparing the process categories that produce the most emissions (Tables 4-7 and 4-8) to those having the highest charge rates (Table 4-6), it is seen that the miscellaneous synthetic rubber production (3-01-026-99) and the ammonium nitrate prilling tower cooler (3-01-027-03) categories have high charge rates, but are not producers of the largest amount of pollutants.

As a check against erroneous data, the effective emission factors from the NEDS data (emissions and charge rate) were compared with data published elsewhere. Although little data were available (data were obtained only from Refs. 4-4 and 4-5), good agreement existed where comparisons could be made. These comparisons plus a general knowledge

(Continued on page 4-15)

Table 4-4. NATIONWIDE POINT SOURCE EMISSIONS[a]

Source Category	Emissions, -- tons/yr			
	PART	NO_x	HC	CO
Fuel Combustion	5,414,427	8,922,937	239,403	645,880
Industrial Processes	8,427,012	3,728,717	7,033,590	21,132,667
Other Point Sources	150,847	29,725	165,847	5,455,023
Total	13,992,286	12,681,379	7,438,840	27,233,570

[a] Ref. 4-3.

Table 4-5. INDUSTRIAL PROCESS EMISSIONS[a]

Source Category	PART	NO_x	HC	CO
Total Industrial Process Emissions, tons/yr				
Chemical Manufacturing: SCC 3-01-xxx-xx	232,886 (2.76%)	155,068 (4.16%)	2,319,544 (32.98%)	5,992,262 (28.36%)
Petroleum Industry: SCC 3-06-xxx-xx	1,036,281 (12.30%)	3,264,812 (87.56%)	1,012,131 (14.39%)	4,524,476 (21.41%)
Other Industrial Processes[b]	7,157,845 (84.94%)	308,837 (8.28%)	3,701,915 (52.63%)	10,615,929 (50.23%)
Total Industrial Processes	8,427,012 (100%)	3,728,717 (100%)	7,033,590 (100%)	21,132,667 (100%)
Total Nationwide Point Source Emissions, %				
Chemical Manufacturing	1.7	1.2	31.2	22.0
Petroleum Industry	7.4	25.7	13.6	16.6
Other Industrial Processes	51.2	2.4	48.8	39.0
Total Industrial Processes	60.2	29.4	94.6	77.6

[a] Ref. 4-3.

[b] Includes such processes as food, agriculture, primary metals, and secondary metals.

Table 4-6. PRODUCERS OF GREATEST EMISSIONS IN CHEMICAL MANUFACTURING

Rank	SCC	Number of Point Sources	Source Category	Annual Production Rate, tons/yr[a]
1	3-01-999-99	1944	Miscellaneous chemical manufacturing	151.29×10^6
2	3-01-026-99	189	Miscellaneous synthetic rubber production	13.63×10^6
3	3-01-021-99	40	Miscellaneous sodium carbonate production	11.67×10^6
4	3-01-018-99	225	Miscellaneous plastics production	5.30×10^6
5	3-01-005-99	74	Miscellaneous carbon black production	4.75×10^6
6	3-01-002-01	33	Ammonia production with methanator	4.62×10^6
7[b]	3-01-027-03	41	Ammonium nitrate with prilling tower	4.25×10^6

[a] Also known as annual charge rate (ACR).

[b] These categories were not among the five categories yielding the greatest emissions in the chemical manufacturing group.

Table 4-7. PRODUCERS OF GREATEST HC EMISSIONS IN CHEMICAL MANUFACTURING

Rank by Emissions

Rank	SCC	Source Category	Effective Emission Factor, lb/ton[a]	Emission Rate, tons/yr
1	3-01-999-99	Miscellaneous chemical manufacturing	6.86	519×10^3
2	3-01-005-01	Carbon black, channel	1767.	227×10^3
3	3-01-002-01	Ammonia with methanator	69.2	160×10^3
4	3-01-005-04	Carbon black, furnace oil	425.	82×10^3
5	3-01-018-99	Miscellaneous plastics production	30.6	81×10^3

Rank by Product

Rank	Product	Production Rate		Emission Rate	
		Tons/yr	%	Tons/yr	%
1	Carbon black	0.634×10^6	0.4	309×10^3	29
2	Ammonia	4.622×10^6	2.9	160×10^3	15
3	Plastics	5.296×10^6	3.3	81×10^3	8
4	Other	151.3×10^6	93.5	519×10^3	49
	Total	161.85×10^6	100	1069×10^3	100

[a] Effective emission factor is the emission rate (lb/yr) divided by the production rate (tons/yr).

Table 4-8. PRODUCERS OF GREATEST CO EMISSIONS IN CHEMICAL MANUFACTURING

Rank by Emissions

Rank	SCC	Source Category	Effective Emission Factor, lb/ton[a]	Emission Rate, tons/yr
1	3-01-005-01	Carbon black, channel	8031.	1032×10^3
2	3-01-005-05	Carbon black, furnace oil and gas	3246.	797×10^3
3	3-01-005-04	Carbon black, furnace oil	2137.	403×10^3
4	3-01-999-99	Miscellaneous chemical	4.44	336×10^3
5	3-01-005-03	Carbon black, furnace gas	5000.	60×10^3
6	3-01-005-99	Carbon black, miscellaneous processes	24.44	58×10^3

Rank by Product

Rank	Product	Production Rate		Emission Rate	
		Tons/yr	%	Tons/yr	%
1	Carbon black	5.90×10^6	3.8	2350×10^3	87
2	Miscellaneous chemical manufacturing	151.29×10^6	96.2	336×10^3	13
	Total	157.19×10^6	100	2686×10^3	100

[a] Effective emission factor is the emission rate (lb/yr) divided by the production rate (tons/yr).

of the subject process resulted in the elimination of synthetic rubber and ammonium nitrate manufacturing as major contributors of the four emissions of interest.

4.3.1 Chemical Manufacturing Processes Studied

As mentioned, only unburned HC and CO emissions were examined when forming the list of products and SCCs for which future charge rate and emission forecasts were to be made. All SCC categories related to an offending product were studied regardless of the magnitude of the current emissions represented by any one SCC. Table 4-7 shows that certain carbon black, ammonia, and miscellaneous chemical manufacturing emissions represent 93 percent of the HC emitted by the five largest producers in the chemical manufacturing category. Table 4-8 shows that certain carbon black manufacturing processes produce the most CO emissions in the chemical manufacturing group.

The chemical manufacturing products and SCC categories for which future emissions and production rates were projected are as follows:

SCC	Product
3-01-002-xx	Ammonia made with methanator
3-01-003-xx	Ammonia made with CO absorber
3-01-005-xx	Carbon black
3-01-999-99	Miscellaneous chemical manufacturing

These four broad categories were divided into 19 MSCC categories, and a current data base and projections were made for each. More detailed definitions of these processes, as well as charge rates, are listed in Table 4-1.

4.3.2 General Observations

In the course of the chemical manufacturing emissions study, certain errors and discrepancies were noted in the NEDS point source emission data. Most of these observations were trivial, but two were believed sufficiently significant to be reported here.

4.3.2.1 Summary of Point Source Comparison

The charge rate (production) and emissions as extracted from the NEDS point source data (Ref. 4-6) are shown in Table 4-9 for the chemical manufacturing group. Although the years of record vary from 1969 to 1973 for the NEDS data, the preponderance of SCC data is for 1971. The emissions from Refs. 4-3, 4-6, and 4-7 are summarized in the following table and are presented graphically in Figure 4-1.

	Emissions, million tons/yr			
Data Source	PART	NO_x	HC	CO
NEDS Tape:				
1971	0.28	0.33	1.42	2.92
NEDS Nationwide Emission Summary Report:				
December 1973	0.22	0.15	2.37	6.01
January 1975	0.23	0.16	2.33	5.99

A discontinuity appears to exist between the 1971 and the 1974-75 data shown in Figure 4-1, indicating an inconsistency in ground rules or methods of establishing the two sets of data. Two known factors which may have contributed to the inconsistency are listed here. Their exact effects are unknown, but are believed to be significant.

a. Emissions listed on the NEDS tape are based frequently on preliminary (sometimes inaccurate) emission factors (Ref. 4-4) or in some cases simply a guess. A comparison of emission factors published in Refs. 4-4 and 4-5 reflects the size of certain data errors. These could cause either high or low emissions to be entered on the NEDS tape.

Table 4-9. SUMMARY OF CHEMICAL MANUFACTURING AND EMISSIONS REPORTED IN NEDS[a]

SCC	Annual Charge Rate[b]	Emissions, ~ tons/yr			
		PART	NO_x	HC	CO
3-01-002-01	4,621,676	118	3,259	160,008	2,777
3-01-002-02	766,500	-	-	-	-
3-01-002-99	-	-	-	-	-
3-01-002		118 (-%)	3,259 (1.0%)	160,008 (11.3%)	2,777 (0.1%)
3-01-003-01	679,793	40	65	772	10,995
3-01-003-02	651,996	119	-	2,510	-
3-01-003-03	486,877	-	-	-	-
3-01-003-99	330,000	-	-	331	-
3-01-003		159 (0.1%)	65 (-%)	3,613 (0.3%)	10,995 (0.4%)
3-01-005-01	257,163	22,146	-	227,337	1,031,710
3-01-005-02		-	-	-	-
3-01-005-03	24,381	3,614	-	19,997	63,469
3-01-005-04	376,731	901	435	82,204	402,659
3-01-005-05	491,484	7,168	10	54,013	797,087
3-01-005-99	4,745,552	8,079	68	8,967	57,506
3-01-005		41,908 (15.2%)	513 (0.2%)	392,518 (27.7%)	2,352,431 (80.7%)
3-01-999-99	151,288,357	69,015 (25.0%)	44,054 (13.3%)	518,506 (36.5%)	335,500 (11.5%)
3-01-008	248,813 (100 tons/yr)	343 (0.1%)	55,730 (16.8%)	- (-)	144 (-%)
3-01-033-01	3,000 (gal/yr)	- (-)	- (-)	5,801 (0.4%)	- (-)
3-01-900-99	747 (million cu ft/yr)	4,667 (1.7%)	146 (-)	- (-)	18,850 (0.6%)
Other 3-01	182,696,930	159,870 (57.9%)	228,523 (68.8%)	338,554 (23.9%)	194,503 (6.7%)
Total		276,080 (100%)	332,290 (100%)	1,419,000 (100%)	2,915,200 (100%)

[a] Extracted from Ref. 4-6.

[b] Unless otherwise specified, charge rate units are in tons of product per year.

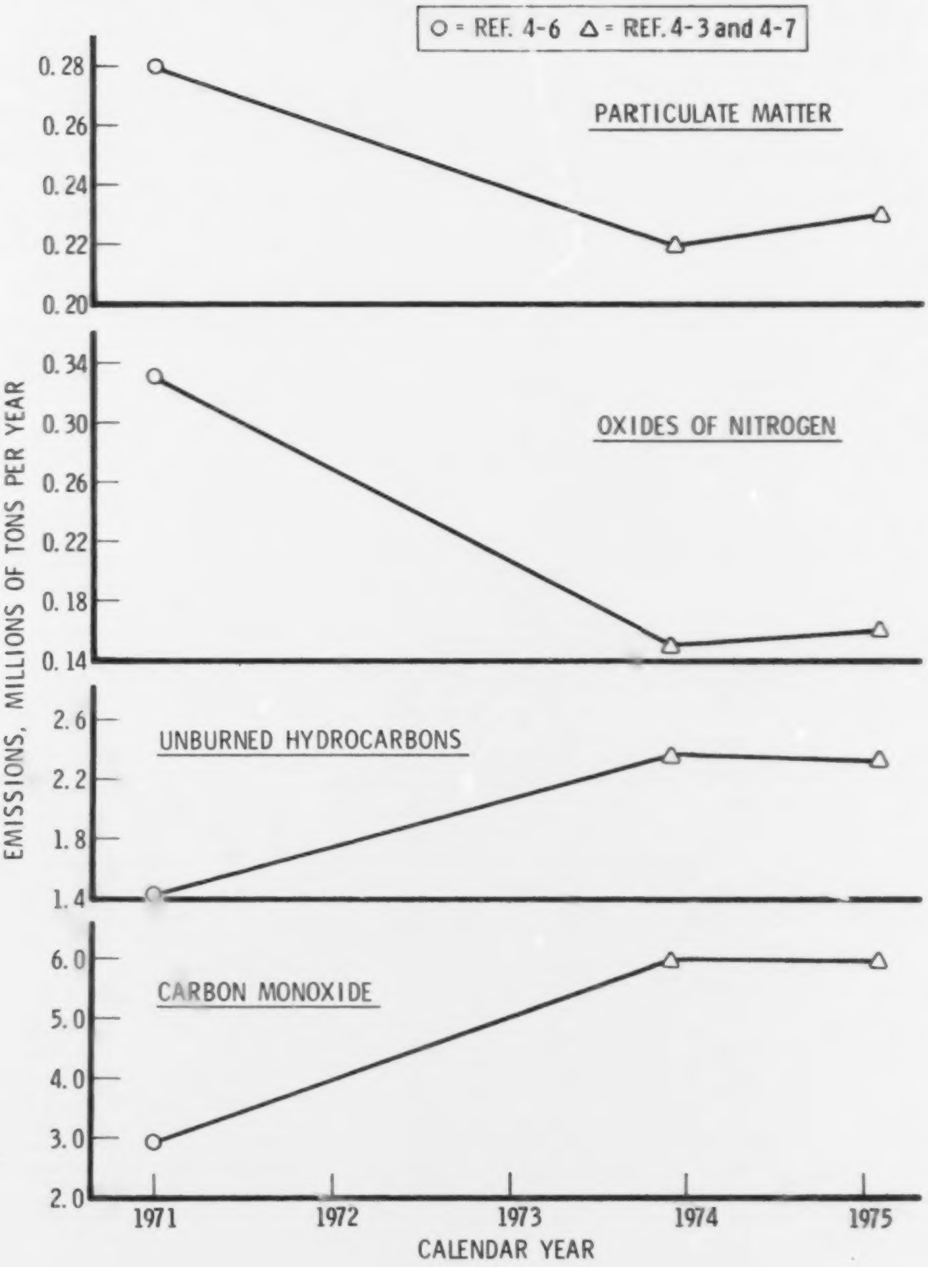

Figure 4-1. Emissions from chemical manufacturing

b. Emissions listed in the summary reports (Refs. 4-3 and 4-7) are based on the product of charge rate and known emission factors. Where the emission factors are not known, zero emissions are entered. This characteristic can only cause the summary report emissions to be low.

4.3.2.2 Lack of Thermal Carbon Black Data

No data were reported under SCC 3-01-005-020 thermal carbon black production. Reference 4-8 shows a steady growth from 47,000 tons in 1950 to 137,000 tons in 1965. Approximately 170,000 tons should have been reported in 1970 according to the trend reported in Ref. 4-8. Total carbon black production in 1970 as extracted from the NEDS falls on the trend line established from Ref. 4-8 only if some production other than that reported in the SCC categories 3-01-005-01, -03, -04, and -05 existed. The difference is close to the forecast production of thermal black in the Ref. 4-8 data. Either thermal carbon black was not reported or it was erroneously reported in SCC 3-01-005-99. Normally, this SCC would be used to report carbon black handling or the manufacturing of some product where carbon black is a principal ingredient. That portion of SCC 3-01-005-99 corresponding to Standard Industrial Classification (SIC) 2895 is close to the deficit. Of the nine SICs comprising SCC 3-01-005-99, SIC 2895 is the only one identified as carbon black.

4.3.3 Ammonia Production

4.3.3.1 Process Description

Two principal methods of ammonia (NH_3) production exist:

a. Methanator process

b. CO absorber process

Both processes combine nitrogen (N) from the atmosphere with hydrogen (H_2) from some hydrocarbon (HC) feed stock such as natural gas. The difference in the two techniques is centered on how the large amounts of CO are handled. The CO results when H_2 is extracted from the HC feed stock. While the CO emissions in the main process of ammonia production are substantially less in the CO absorber technique, the CO efflux from the absorber when it is being rejuvenated tends to be quite high. An extensive water scrubber and incinerator system can considerably reduce the CO emissions during absorber regeneration.

Unburned HC emissions (usually methane) from the purge gas stream are of the same concentration whether the methanator or CO absorber system is used. Scrubbers have a modest effect on HC emissions.

Although beyond the scope of this study, another noteworthy emission is ammonia vapor. This emission can be reduced to almost any level of insignificance through repeated water scrubber application.

4.3.3.2 Data Research and Analysis

Production rates* of synthetic ammonia are recorded in Refs. 4-6 and 4-9. The charge rate history is graphically presented in Figure 4-2. Several straight lines were derived by least square fit techniques from various combinations of the data points on Figure 4-2. The straight line obtained when 1964 and 1965 data were excluded yielded the best correlation. Its equation was used when estimating future ammonia production. The uncertainty in baseline production is simply the standard error of estimate obtained with the straight line derivation. The uncertainty of the production slope is the difference in slope for the adopted line and the line derived using the six data points in Figure 4-2. This number is approximately 21 percent of the baseline value.

The total production reflected in Figure 4-2 is considered to be apportioned among the six SCC categories for all years in the same percentage as that listed by the NEDS for the 1970-72 era. Emission factor data are found in three areas:

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*The term "production rate" as used here refers to the charge rate associated with the particular operation; e.g., SCC 3-01-002-02 is related to storage and loading, and the ammonia charge rate was actually produced or created under 3-01-002-01 for methanator systems. The production SCC for CO absorption systems is 3-01-003-02.

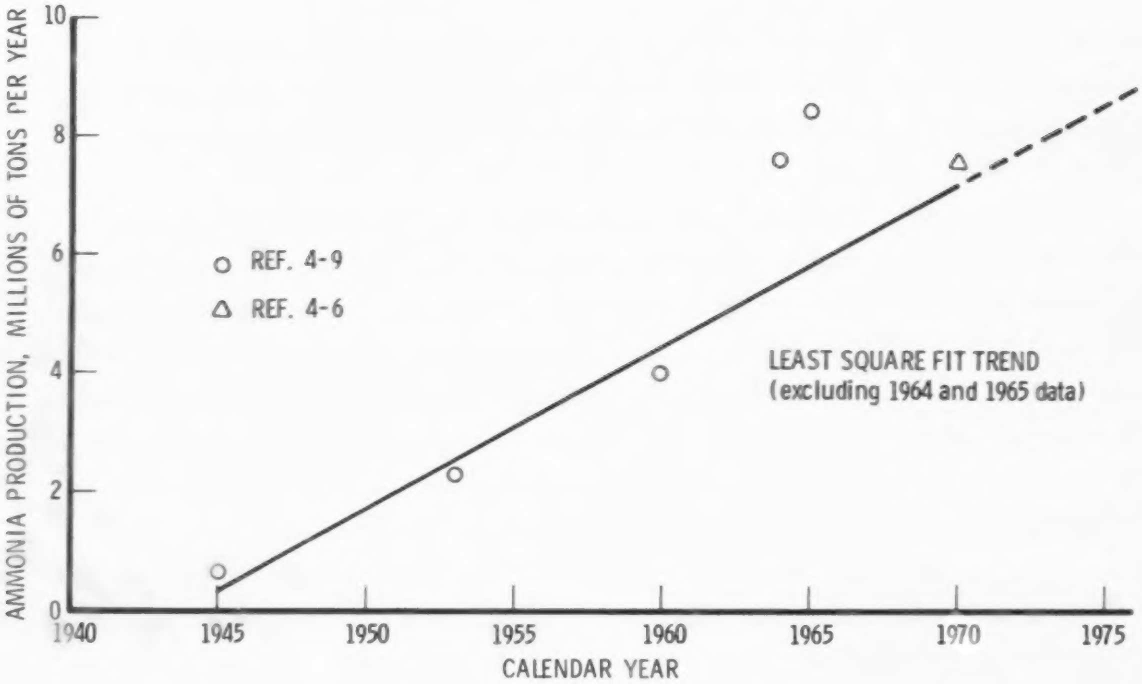

Figure 4-2. Synthetic ammonia production

a. Reference 4-5

b. Reference 4-10

c. Quotient of emissions and charge rate from Ref. 4-6 data.

Where emission factor data exist in Ref. 4-10, they are considered to supersede Ref. 4-5 data. In the following discussion, that which prevails between Refs. 4-5 and 4-10 will be referred to as the "EPA emission factor."

Where reasonable agreement (i.e., less than 15 percent difference) exists between the EPA emission factor and that derived from the NEDS data, the average of the two was established as the baseline value. Where the difference was great, a third source was enlisted as a referee; where no third source was available, engineering judgment was exercised on the basis of knowledge of the process in question. The uncertainty in the baseline emission factor is simply the difference between the baseline value and the nearest source value which contributed to its derivation.

As mentioned, PART and NO_x emissions from chemical manufacturing were so small (Table 4-7) in comparison to the total industrial process that no time was spent in establishing their emission factors (or related variables like slope or uncertainties); these emissions were defined as negligible for all future years.

The literature survey described ammonia production processes as having remained essentially unchanged since 1953, and no substantial changes in controls or process are forecast for the immediate future. As a result, the slope and the slope uncertainties for ammonia emission factors were set to zero.

4.3.3.3 Projections of Ammonia Activity

The total HC emission from ammonia production in 1982 is estimated to be 256,000 tons ± 35,000. The majority (223,000 tons) of these emissions is from methanator-type production. The total estimated CO emissions from ammonia industries in 1982 is 59,000 tons ± 38,000. The NO_x and PART emissions are expected to be negligible in 1982 (as is the case presently) compared to other point source industrial processes emissions.

4.3.4 Carbon Black Industry

4.3.4.1 Processes and Uses

Carbon black is an oil-free ultrafine soot. Although it is used in the paint and printing industry as a pigment, the prominent use is in the rubber industry as a reinforcing agent. Tires, for example, roll three to five times farther with carbon black than without.

Three principal techniques of carbon black production exist:

a. Impingement process
b. Thermal process
c. Furnace process

The furnace process, which accounts for most carbon black production, is subdivided further according to fuel type: oil, natural gas, and oil-enriched natural gas.

The impingement and thermal processes involve incomplete combustion of HC fuel, whereas the thermal process involves thermal decomposition (or cracking) of natural gas by exposing it to heated (2400° to 2800°F) brick work. The impingement process (also called channel process) involves natural gas-fueled flames impinging on surfaces of steel (usually channel cross section) and depositing carbon black. The carbon black is periodically scraped off the channels before pelletizing (to increase the density for more economical shipment) for packaging and shipment. Channel black is one of the finest (20 to 50 nm particle size) grades made. Furnace black particle size is 25 to 160 nm. Although the thermal process produces a much larger particle size (150 to 500 nm) and consequently facilitates control of particulate-type HC emissions, many users of carbon black, such as tire manufacturers, simply cannot use this product. The furnace process employs refractory-lined furnace combustion chambers where the natural gas and oil is burned with insufficient air. The process is continuous in nature, whereas the thermal and impingement processes are cyclic. Furnace reactors have grown to be sophisticated efficient plants compared to the channel black burner houses. The latter are normally temporarily set up at the source of cheap natural gas and involve few controls (except for air flow). Gas furnaces yield 12 to 16 lb of carbon black per 1000 cu ft of gas compared to a yield of 2 to 3 lb/1000 cu ft from the channel black process. The theoretical yield is approximately 32 lb/1000 cu ft.

By its nature, carbon black production is a high emitter of HC and CO. Although much of the following practice was implemented to improve efficiency, pollution control benefits are inherent. Since most HC emission are in the form of soot particulate, the most common forms of alleviation are cyclone separators; water scrubbers; bag filters; and, more recently, electrostatic percipitators. Also some consideration has been given to burning HC emissions. This would alleviate the flow of gaseous emissions such as methane as well as the fine particulate soot. CO emissions are left essentially uncontrolled in carbon black production.

4.3.4.2 Data Research and Analysis

4.3.4.2.1 Carbon Black Production

Production rates of carbon black are listed in Ref. 4-8 for selected years from 1925 to 1965. Production rates for 1970 are recorded in Ref. 4-6. With some difficulty, the data from Ref. 4-8 for the years 1950, 1955, 1960, and 1965 were merged with the Ref. 4-6 data to establish a modern-day trend. Two problems were encountered:

a. The Ref. 4-8 furnace data were not broken down by type, i.e., oil, gas, or oil and gas.

b. No production rates were recorded in Ref. 4-6 for thermal black.

Problem a. was disposed of by assuming Ref. 4-8 furnace charge rates were apportioned among the three processes on a percentage basis the same as the Ref. 4-6 data.

The trend of total carbon black production for 1970 follows the same curve as Ref. 4-8 data only if some carbon black production exists other than that reported in Ref. 4-6 under the SCC categories 3-01-005-01, -03, -04, and -05. As seen in Figure 4-3, the deficit closely matches the charge rate reported under SIC 2895 of SCC 3-01-005-99. These observations (plus the fact that corporations listed in the NEDS point source data were involved in other carbon black production) led to defining the 1970 production as the sum of the charge rate for the four previously mentioned SCC categories and the portion of SCC 3-01-005-99 allocated to SIC 2895. Products corresponding to SIC classifications are defined in Ref. 4-1. Figure 4-4 shows the production rate of carbon black for the five processes under these ground rules.

Trend curves were established for the production rate of each process by deriving the least square fit straight line using various combinations of the 1955 to 1970 data. Figure 4-4 shows the curve which used all five sets of data between 1950 and 1970. Even though the 1950-65 data resulted in a better fit (higher correlation coefficient), it was decided to use (for future black production estimates) those curves derived from all five points (1950 to 1970). The rationale was as follows:

a. The inclusion of the latest data (1970) adds credence to future estimates.

b. Use of data from several sources offsets errors in individual data where checking for validity is not possible.

These trend curves were used to establish baseline production in the year 1975. The uncertainty in baseline production is equal to the standard error of estimate obtained in deriving the straight line. The uncertainty of the baseline slope (change in production rate per year) was defined as the difference in slope of straight lines using all five points and that excluding the 1970 data.

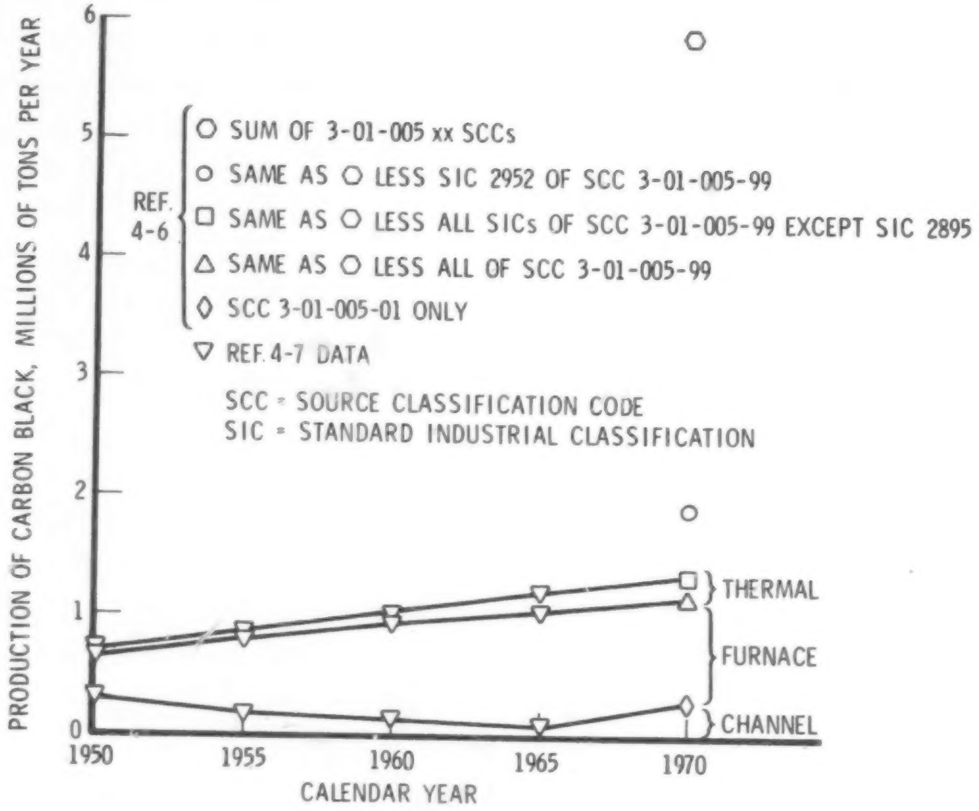

Figure 4-3. Total carbon black production

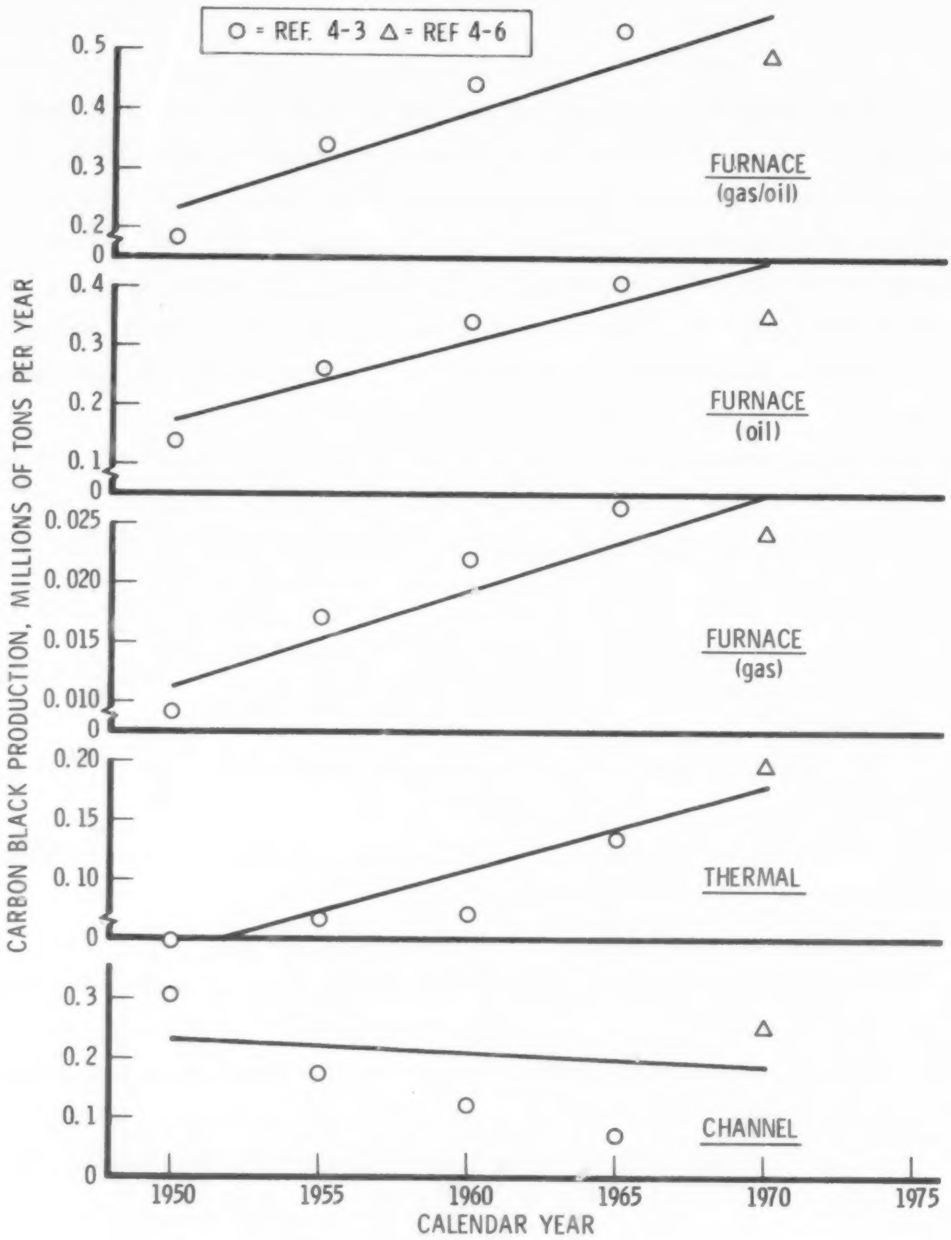

Figure 4-4. Breakdown of carbon black production

Emission factors for carbon black production are reported in Refs. 4-5 and 4-10 and also can be calculated by dividing the pounds of emissions by the tons of carbon black produced from Ref. 4-6. Data in Ref. 4-10 for a particular process were considered an update of Ref. 4-5 data. Reference 4-5 or 4-10 data (whichever prevail) is referred to as the "EPA emission factor." The other source is called the "NEDS emission factor." Where reasonable agreement (i.e., ≤ 15 percent difference) exists between the EPA and NEDS emission factors, the average of the two values was established as baseline and its uncertainty was the difference between the baseline value and the parent data.

Three cases were encountered where the EPA emission factor differed substantially from the one based on the NEDS data:

a. Hydrocarbon emission factor for channel process

b. Carbon monoxide emission factor for channel process

c. Carbon monoxide emission factor for oil-fed furnace.

It was reasoned that the emission factors should be inversely proportional to the percent theoretical product yield.

The theoretical maximum yield of carbon black is 32 lb/1000 cu ft of natural gas. However, according to Ref. 4-11, approximately 40 percent of this HC is needed to raise the temperature sufficiently to separate the carbon. Therefore, if none of the 32 lb of carbon black were collected, approximately 19 lb would escape to the atmosphere, and the remainder would be consumed to heat the gas. Stated mathematically, the hypothesis is as follows:

$$\frac{EF_1}{EF_2} = \frac{(1.0 - 0.4 - \eta_1)\,\eta_2}{(1.0 - 0.4 - \eta_2)\,\eta_1}$$

where

EF = emission factor

η = decimal fraction of 32 lb that the process yields of carbon black

Since the emission factor for furnace process with gas was known (i.e., good agreement between the EPA emission factor and the one derived from the NEDS), it was used as a basis to establish the three discrepant emission factors. This approach yielded values so close to the ones derived from the NEDS data that the latter was selected for channel baseline emission factors.

In the case of the oil-fired furnace process, the baseline CO emission factor was defined as five percent higher than the one based on NEDS data.

4.3.4.2.2 Miscellaneous Carbon Black Processes

Data were prepared to allow projections to be made in the five MSCC categories of the miscellaneous carbon black industry (MSCC 3-01-005-99). These MSCC categories were based on the SIC classifications listed below and their corresponding products and comprised the point sources under SCC 3-01-005-99 in Ref. 4-6 of the NEDS data:

MSCC	SIC	Product
3-01-005-99-1	2952	Asphalt, felts, and coatings
3-01-005-99-2	3624	Carbon and graphite products
3-01-005-99-3	3999	Manufacturing industries NEC[a]
3-01-005-99-4	2899	Chemical preparation NEC
3-01-005-99-5	3334 3069 3991 2999	Primary aluminum Fabricated rubber products Brooms and brushes Petroleum and coal products

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[a] Not elsewhere classified (NEC).

The baseline charge rate was set equal to the NEDS (1970) value. Uncertainties were set at 5 percent of the base value for categories MSCC 3-01-005-99-1 through 3-01-005-99-4 and to 10 percent for MSCC 3-01-005-99-5, which is a bigger uncertainty since it is comprised of a broad collection of activities. Typical uncertainty of the carbon black production is eight percent.

The baseline emission factors were set equal to the NEDS emissions divided by the charge rate. The emission factor uncertainty was set to 10 percent of baseline value, which was typical of the primary carbon black production SCC categories.

Since little is known about the production and processes in this miscellaneous manufacturing group, no attempt was made to establish a finite slope (trend) or slope uncertainty of any of the data leading to projections of the 3-01-005-99 SCC categories.

4.3.4.3 Projections of Carbon Black Activity

The estimated HC emissions in 1982 carbon black industries are 331,000 tons. Although the channel process is by far the dirtiest (high emission factor), its HC emissions are down both trend-wise and process-wise. The 1982 HC emissions from channel black production is 86,000 tons compared to 121,000 for the oil-fired furnace process. The estimated channel black HC emissions in 1975 are 112,000 tons.

The estimated CO emissions from carbon black in 1982 are 2.42-million tons. The oil-enriched natural gas-fired furnace technique leads CO emissions with 1.22-million tons in 1982.

4.3.5 Miscellaneous Chemical Manufacturing

4.3.5.1 Products

Some 78 separate products (SIC classifications) at 1944 point sources comprised the miscellaneous chemical manufacturing (SCC 3-01-999-99) categories in the NEDS data tape. Entries made under

SIC 2818 and 3999, respectively, constituted approximately 50 percent of the HC and CO emissions. The 76 other SIC products combined represented only 43 percent of the HC and 35 percent CO emissions. Emission projections were made for three subdivisions of miscellaneous chemical manufacturing: (1) SIC 2818, (2) SIC 3999, and (3) remainder (other than SIC 2818 and 3999). SIC 2818 was not defined in Ref. 4-1, but such a classification would be a member of the industrial inorganic chemicals under SIC 281x.

SIC 3999 designates manufacturing industries NEC.

4.3.5.2 Data Definition

The baseline charge rates and emission factors for each category were set equal to the value calculated from the NEDS data (Ref. 4-6). The uncertainties in charge rates and emission factors were based on other chemical manufacturing (ammonia and carbon black).

Slopes and slope uncertainties were set to zero since little is known about the collage of industrial activity.

4.3.5.3 Projections of Miscellaneous Chemical Manufacturing

The estimated 1982 HC and CO emissions from miscellaneous chemical manufacturing are 518,000 ± 65,000 tons and 336,000 ± 129,000 tons, respectively.

4.4 REFERENCES

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4-2. Guide for Compiling a Comprehensive Emission Inventory, Revised, APTD-1135, U.S. Environmental Protection Agency, Research Triangle Park, North Carolina (March 1973).

4-3. NEDS Nationwide Emissions Report as of January 10, 1975 (with New York and West Virginia Supplement), U.S. Environmental Protection Agency, Research Triangle Park, North Carolina (February 12, 1975).

4-4. *Compilation of Air Pollutant Emission Factors*, AP-42, U.S. Environmental Protection Agency, Research Triangle Park, North Carolina (February 1972).

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4-6. "Industrial Processes, Chemical Manufacturing Category," NEDS Data, *The Aerospace Corporation Tape Analysis*, The Aerospace Corporation, El Segundo, California (February 25, 1975).

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4-9. R. Shreve, *Chemical Process Industries*, 3rd ed., McGraw Hill Book Co., Inc., New York (1967).

4-10. *NEDS Source Classification Codes and Emission Factor Listing* (SCC Listing), U. S. Environmental Protection Agency, Research Triangle Park, North Carolina (July 1974).

4-11. T. Cox, Jr., "High Quality-High Yield Carbon Black," *Chemical Engineering Journal* (June 1950).

SECTION V

PETROLEUM REFINERIES

5.1 INTRODUCTION

This section develops data for the petroleum refining industry, in terms of several important source classification codes (SCC), for emissions of particulate (PART) matter, nitrogen oxides (NO_x), unburned hydrocarbons (HC), and carbon monoxide (CO).

The purpose is to provide a general overview of the petroleum refining industry, assess the importance of specific major process sources of atmospheric emissions, estimate current and projected levels, provide the rationale used in making the projections, and present the data sources. Table 5-1 describes the process and charge rate units for each SCC studied.

5.2 SUMMARY

Petroleum industry annual charge rates and emission rates were established. Data for two sample years are reported in Tables 5-2-a and 5-3-a, respectively. The uncertainty data are listed in Tables 5-2-b and 5-3-b.

5.3 APPROACH

Developing and forecasting emission inventories requires knowledge or judgment about a combination of factors. Technological generalities are discussed in Section 5.7. Two important elements are total annual charge rates and emission factors. Judgments have been made about expected changes in these parameters resulting from technology advancements,

(continuted on page 5-9)

Table 5-1. DEFINITION OF PETROLEUM INDUSTRY PROCESSES

MSCC	Source Category	Charge Rate Unit
306001010	Process heater (oil-fired, major quantities)	1000 bbl burned/yr
306001020	Process heater (gas-fired, minor quantities)	1000 cu ft burned/yr
306001030	Process heater (oil-fired, minor quantities)	1000 gal burned/yr
306001040	Process heater (gas-fired, major quantities)	Million cu ft burned/yr
306002010	Fluid catalytic cracking	1000 bbl fresh feed/yr
306003010	Moving bed catalytic cracking	
306008010	Miscellaneous leakage (pipe, valve, flange)	1000 bbl refined/yr
306008020	Miscellaneous leakage (vessel relief valves)	1000 bbl refined/yr
306008030	Miscellaneous leakage (pump seals)	1000 bbl refined/yr
306008040	Miscellaneous leakage (compressor seals)	1000 bbl refined/yr
306008050	Miscellaneous leakage (other, general)	1000 bbl refined/yr
306012010	Fluid coking	1000 bbl fresh feed/yr

Table 5-2-a. 1977 PETROLEUM INDUSTRY EMISSIONS AND CHARGE RATES

INDUSTRIAL PROCESS, PETROLEUM PRODUCTS PAGE 1

ANNUAL CHARGE RATES AND EMISSIONS PROJECTED TO 1977 RUN DATE= NOV 16,1977

MODIFIED SCC	TACRF (SCC UNITS)	EMISSIONS (MILLIONS OF TONS / YEAR) NOX	HC	CO	PART
306001000		.435	.049	.136	.090
306001010	141320.	.164	.010	.012	.059
306001020	2560000000.	.255	.038	.022	.025
306001030	586700.	.016	.001	.001	.005
306001040	NEG	NEG	NEG	NEG	NEG
306002000	1576000.	.053	.174	14.859	.161
306002010	1576000.	.053	.174	14.859	.161
306003000	93100.	NEG	.004	.177	NEG
306003010	93100.	NEG	.004	.177	NEG
306008000	27690000.	NEG	.198	NEG	NEG
306008010	5610000.	NEG	.079	NEG	NEG
306008020	5610000.	NEG	.031	NEG	NEG
306008030	5610000.	NEG	.048	NEG	NEG
306008040	5250000.	NEG	.013	NEG	NEG
306008050	5610000.	NEG	.028	NEG	NEG
306012000	114000.	NEG	NEG	NEG	.028
306012010	114000.	NEG	NEG	NEG	.028

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Table 5-2-b. 1977 PETROLEUM INDUSTRY UNCERTAINTIES

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                 INDUSTRIAL PROCESS, PETROLEUM PRODUCTS                      PAGE   1
TACF AND EMISSION UNCERTAINTIES PROJECTED TO 1977          RUN DATE= NOV 16,1977
 MODIFIED        TACRF                  EMISSIONS (MILLIONS OF TONS / YEAR)
   SCC        (SCC UNITS)           NOX              HC               CO               PART

306001000                         +  .027         +  .006         +  .005          +  .005
                                  -  .027         -  .006         -  .005          -  .005

306001010     +        8601.      +  .014         +  .005         +  .002          +  .005
              -        8601.      -  .014         -  .005         -  .002          -  .005
306001020     +   159860000.      +  .022         +  .003         +  .005          +  .002
              -   159860000.      -  .022         -  .003         -  .005          -  .002
306001030     +       35456.      +  .007         +  .000         +  .000          +  .002
              -       35456.      -  .007         -  .000         -  .000          -  .002
306001040             NEG             NEG             NEG              NEG              NEG
                      NEG             NEG             NEG              NEG              NEG

306002000     +       72971.      +  .004         +  .012         + 6.216          +  .011
              -       72971.      -  .004         -  .012         - 6.216          -  .011

306002010     +       72971.      +  .004         +  .012         + 6.216          +  .011
              -       72971.      -  .004         -  .012         - 6.216          -  .011

306003000     +        8633.          NEG         +  .000         +  .019              NEG
              -        8633.          NEG         -  .000         -  .019              NEG

306003010     +        8633.          NEG         +  .000         +  .019              NEG
              -        8633.          NEG         -  .000         -  .019              NEG

306008000     +      590690.          NEG         +  .036              NEG              NEG
              -      590690.          NEG         -  .036              NEG              NEG

306008010     +      264160.          NEG         +  .028              NEG              NEG
              -      264160.          NEG         -  .028              NEG              NEG
306008020     +      264160.          NEG         +  .011              NEG              NEG
              -      264160.          NEG         -  .011              NEG              NEG
306008030     +      264160.          NEG         +  .017              NEG              NEG
              -      264160.          NEG         -  .017              NEG              NEG
306008040     +      264160.          NEG         +  .005              NEG              NEG
              -      264160.          NEG         -  .005              NEG              NEG
306008050     +      264160.          NEG         +  .010              NEG              NEG
              -      264160.          NEG         -  .010              NEG              NEG
```

Table 5-2-b. 1977 PETROLEUM INDUSTRY UNCERTAINTIES (Continued)

```
                    INDUSTRIAL PROCESS, PETROLEUM PRODUCTS                       PAGE  2
        TACF AND EMISSION UNCERTAINTIES PROJECTED TO 1977        RUN DATE= NOV 16,1977
 MODIFIED          TACFF                  EMISSIONS (MILLIONS OF TONS / YEAR)
   SCC          (SCC UNITS)         NOX              HC              CO         PART

306012000   +        5205.          NEG              NEG             NEG      +  .002
            -        5205.          NEG              NEG             NEG      -  .002

306012010   +        5205.          NEG              NEG             NEG      +  .002
            -        5205.          NEG              NEG             NEG      -  .002
```

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Table 5-3-a. 1982 PETROLEUM INDUSTRY EMISSIONS AND CHARGE RATES

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                    INDUSTRIAL PROCESS, PETROLEUM PRODUCTS                   PAGE  1
ANNUAL CHARGE RATES AND EMISSIONS PROJECTED TO 1982      RUN DATE= NOV 16,1977
 MODIFIED          TACRF                EMISSIONS (MILLIONS OF TONS / YEAR)
   SCC          (SCC UNITS)         NOX              HC             CO            PART

 306001000                          .253            .069           .039           .077

 306001010           93134.         .041            .007           .008           .039
 306001020      3460000000.         .206            .052           .030           .035
 306001030          586700.         .006            .001           .001           .003
 306001040             NEG           NEG             NEG            NEG            NEG

 306002000         1766000.         .059            .183          3.826           .102

 306002010         1766000.         .059            .183          3.826           .102

 306003000           54600.          NEG            .002           .100            NEG

 306003010           54600.          NEG            .002           .100            NEG

 306008000        31290000.          NEG            .226            NEG            NEG

 306008010         6510000.          NEG            .092            NEG            NEG
 306008020         6510000.          NEG            .035            NEG            NEG
 306008030         6510000.          NEG            .055            NEG            NEG
 306008040         5250000.          NEG            .013            NEG            NEG
 306008050         6510000.          NEG            .032            NEG            NEG

 306012000          124000.          NEG             NEG            NEG           .030

 306012010          124000.          NEG             NEG            NEG           .030
```

Table 5-3-b. 1982 PETROLEUM INDUSTRY UNCERTAINTIES

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                    INDUSTRIAL PROCESS, PETROLEUM PRODUCTS                          PAGE  1
 TACF AND EMISSION UNCERTAINTIES PROJECTED TO 1982            RUN DATE= NOV 16,1977
 MODIFIED           TACRF               EMISSIONS (MILLIONS OF TONS / YEAR)
   SCC          (SCC UNITS)         NOX               HC               CO               PART
 306001000
                                 +  .034          +  .007          +  .007          +  .008
                                 -  .034          -  .008          -  .007          -  .008

 306001010   +        13650.     +  .003          +  .003          +  .002          +  .006
             -        13650.     -  .009          -  .003          -  .002          -  .006
 306001020   +    420640000.     +  .032          +  .007          +  .007          +  .005
             -    420640000.     -  .032          -  .007          -  .007          -  .005
 306001030   +        77064.     +  .007          +  .000          +  .000          +  .001
             -        77064.     -  .005          -  .000          -  .000          -  .001
 306001040              NEG         NEG              NEG              NEG              NEG
                        NEG         NEG              NEG              NEG              NEG

 306002000   +       234740.     +  .008          +  .026          + 7.021          +  .015
             -       234740.     -  .008          -  .026          - 7.021          -  .015

 306002010   +       234740.     +  .008          +  .026          + 7.021          +  .015
             -       234740.     -  .008          -  .026          - 7.021          -  .015

 306003000   +        29326.        NEG           +  .001          +  .054             NEG
             -        29326.        NEG           -  .001          -  .054             NEG

 306003010   +        29326.        NEG           +  .001          +  .054             NEG
             -        29326.        NEG           -  .001          -  .054             NEG

 306008000   +      1911600.        NEG           +  .044             NEG              NEG
             -      1911600.        NEG           -  .044             NEG              NEG

 306008010   +       854870.        NEG           +  .034             NEG              NEG
             -       854870.        NEG           -  .034             NEG              NEG
 306008020   +       854870.        NEG           +  .013             NEG              NEG
             -       854870.        NEG           -  .013             NEG              NEG
 306008030   +       854870.        NEG           +  .021             NEG              NEG
             -       854870.        NEG           -  .021             NEG              NEG
 306008040   +       854870.        NEG           +  .005             NEG              NEG
             -       854870.        NEG           -  .005             NEG              NEG
 306008050   +       854870.        NEG           +  .012             NEG              NEG
             -       854870.        NEG           -  .012             NEG              NEG
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Table 5-3-b. 1982 PETROLEUM INDUSTRY UNCERTAINTIES (Continued)

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                    INDUSTRIAL PROCESS, PETROLEUM PRODUCTS                PAGE  2

TACP AND EMISSION UNCERTAINTIES PROJECTED TO 1982        RUN DATE= NOV 16,1977

 MODIFIED          TACRF                    EMISSIONS (MILLIONS OF TONS / YEAR)
   SCC          (SCC UNITS)           NOX              HC               CO            PART

306012000    +       16658.            NEG              NEG              NEG          +  .005
             -       16658.            NEG              NEG              NEG          -  .005

306012010    +       16658.            NEG              NEG              NEG          +  .005
             -       16658.            NEG              NEG              NEG          -  .005
```

regulatory impacts, economic considerations, and other matters. Development of emission factors for the more important SCCs was primarily based upon data provided in Ref. 5-1. The major sources of petroleum refinery emissions stem from combustion-generated emissions resulting from process heating and catalyst regeneration, while HC discharges result mainly from sources of leakage or evaporation.

In certain instances, revisions of CO factors were made for consistency with other firing equipment using similar fuels or known data. For example, the CO emission factor for oil-fired process heaters in SCC 3-06-001-01 is indicated as zero. The corresponding CO emission factor for external combustion boilers (SCC 1-02-004-xx and 1-02-005-xx) indicates 4-lb CO/1000 gal burned, which is equivalent to 168 lb/1000 bbl. The factor used in this instance was accordingly taken as 170 for equipment in this SCC.

In a similar way, it can be determined that CO variation in fluid catalytic cracking introduces uncertainty in the emission factor for SCC 3-06-002-01. The factor given for this effluent in Ref. 5-1 is 13,700-lb CO/SCC. Coke formation ranges between 4 and 10 percent of fresh feed charge. The amount of CO produced varies with the stoichiometry within the regenerator, but a range may be assessed in a simple way by assuming that the CO_2/CO ratio in the off gases is 1.5, which is typical (Ref. 5-2). On the basis of an 8 percent coke formation and a feed gravity of 300 lb/bbl, we have

$$5C + 4O_2 = 2CO + 3CO_2$$

$$\frac{8\text{-lb coke}}{100\text{-lb fresh feed}} \times \frac{56\text{-lb CO}}{60\text{-lb coke}} \times \frac{300\text{ lb}}{\text{bbl}} \times \frac{1000\text{ bbl}}{\text{SCC}} = 22,400\text{-lb CO/SCC}$$

Slightly different assumptions can be made to show even more severe emission factors, which merely makes the uncertainty range greater.

5.4 GENERAL REFINERY STATISTICS

Statistical data from several sources served as the basis for obtaining detailed information concerning crude charging rates, production capacities, product yields, and past production trends. Most refiners try to maximize gasoline and fuel production, although some operators concentrate on other specialty products as well. Average yields and other statistics of U.S. refineries are periodically published by the American Petroleum Institute (API) and also in industry journals such as The Oil and Gas Journal (Ref. 5-3). Percentage yields of various petroleum products for 1973 are represented in Table 5-4. As shown, gasoline represents the major product of the industry; the yield of gasoline relative to crude input is nearly one-half the total volume. This is a composite statistic; some refiners can obtain gasoline yields in excess of 60 percent.

Petroleum refinery statistics dating back to 1956 are given in Ref. 5-2. Few changes in refinery yields have occurred. Average gasoline yields have increased from 43.4 to 45.6 percent. The annual growth rate in crude runs to stills for the entire time period of Ref. 5-2 is 2.7 percent and 3.6 percent over the last 10 years. Gasoline production growth over this same time period has been nearly 4 percent and approximately 3 percent over the entire time period. Thus, refiners have been concentrating their efforts on producing ever increasing amounts of gasoline from crude. The most recent estimates for gasoline production in 1974 is about 6.5×10^6 bbl/day or nearly 10^{11} gal/year. Although kerosene production in Ref. 5-4 appears to have declined, it has been replaced by jet fuels. Total kerosenes therefore, are increased. A considerable decline in residual fuel oil yield from 14.7 percent in 1956 to 7.7 percent in 1973 is indicative of further processing of these "heavy ends."

Recent data on a state-by-state basis show that in early 1974 there were 247 refineries operating in the United States, with a daily stream crude capacity of 14.9×10^6 bbl/day, running at 96 percent capacity (Ref. 5-3). For 1975, the daily runs were estimated at 15×10^6 bbl, which when annualized on 350 days results in 5.25×10^9 bbl. Although this appears to be an

Table 5-4. 1973 DISTRIBUTION OF PETROLEUM PRODUCTS

Product	Percent of Refinery Yield
Gasoline	45.61
Distillate Fuel Oil	22.46
Residual Fuel Oil	7.74
Jet Fuel (Kerosene)	5.41
Kerosene	1.73
Jet Fuel (Naphtha)	1.44
Lubricants	1.50
Other	14.11

exceptional rise in the two-year interim following the last tabulated values of Ref. 5-2, it seems in line with present market demand patterns and industry construction.

A number of reference sources can be cited in forecasting energy demands, sources of supply, or projected growth rate of U.S. consumption (Refs. 5-5 through 5-11). Such issues as economics and industrial activity, population growth, domestic government policies, and related international politics lead to considerable uncertainty in forecasts. In this study, considering an overall oil requirement in the vicinity of 22 to 23 million bbl/day by 1980, refinery runs have been estimated to be in the range of 17 to 18.5 million bbl/day. On an annual charge rate basis, the values are from 6.0×10^9 to 6.3×10^9 bbl/year. When a SCC is measured in terms of 1000 bbl/year, these figures represent projected levels of 6.0 to 6.3×10^6 SCC/year and compare favorably with the long-term and recent-term trends discussed earlier.

5.5 PETROLEUM REFINERY PROCESSES EVALUATED

5.5.1 Process Heaters

Energy consumption requirements of typical refineries were determined to establish the emissions from combustion equipment. Energy used in refining, as in other industrial practices, is governed by fuel price. Nelson (Ref. 5-12) has shown that, for an average refinery, net energy consumption varies with refinery complexity, but for many years has generally remained in the range of 10 to 12 percent of processed crude. Newer refineries tend to have lower energy consumption because refiners have installed more efficient systems, enabling better overall heat utilization. In this study, the net energy consumption level was therefore assumed as 10 percent of 0.63×10^6 Btu/bbl oil processed. About two thirds of this heat is obtained in some plants by the burning of refinery process gases and about one third from the firing of salable liquids or residual fuel (Ref. 5-13). A further breakdown of process heater firing was obtained from a NEDS data tape printout which showed that 92 percent of the oil-fired process heater charge rate is in large heaters (SCC category 3-06-001-01) versus 8 percent in small heaters (SCC 3-06-001-03) (Ref. 5-14).

In forecasting, it was assumed that refineries will continue to increase in complexity (as they have for many years). There are several reasons why this should occur. A large portion of the industry lacks the capability to process high-sulfur crude oil (Ref. 5-15). Therefore, the industry will develop the flexibility to handle such crudes and at the same time will be upgrading production facilities to meet new environmental demands for pollution control and to produce lead-free and low-lead gasoline products. These factors will tend to be offset by certain energy conservation measures; hence, it was assumed that the energy required to operate refineries in the near future will still be 10 percent of the total product processed by these refineries.

The overall energy consumed by oil-fired heaters will tend to decline as fuel-firing strategies will tend toward selection and use of process gaseous fuels having a low sulfur content. This is dictated by recently promulgated regulations (Refs. 5-16 and 5-17) which limit atmospheric sulfuric oxide (SO_2) emissions from process heaters. It has been estimated that a reduction of up to 30 percent of current energy values in SCC 3-06-001-01 can be realized. The implication of this is that future needs for process heat from this SCC will consume only about 25 percent of refinery fuel requirements, with greater implementation of refinery-process gas-fired equipment. At the same time, improved firing techniques will enable reductions in NO_x emission factors.

5.5.2 Fluid Catalytic Cracking

The fluid catalytic cracking capacity of an average refinery is about 30 percent of crude capacity, with larger companies tending to have higher fractions (approximately 34 percent) and smaller companies having lower fractions (24 percent) (Ref. 5-15). The largest fluid catalytic cracking plants operate in the range of 120,000 bbl/day, and there are eight plants of this size range (Ref. 5-3). The total annual charge rate of this SCC is presently 1.5×10^9 bbl/year. Over the past few years, the growth trend has been a fairly consistent 2.4 percent annually, so that by 1980 the expected new additions will account for 1.69×10^9 bbl/year, if no perturbations occur. According to Conn (Ref. 5-18), the attributes of fluid catalytic cracking are that fluid crackers (1) may be constructed in very large sizes, (2) are relatively free of mechanical problems, and (3) have proven flexible in operation.

As mentioned, several important advances have taken place in fluid catalytic cracking. These include improved catalysts and improved operating and regeneration techniques (such as riser cracking and two-stage regeneration) resulting in improved capacities and yields (Ref. 5-19), lower coke make, and lower emissions (Ref. 5-20). The rising trend in fluid cracking capacity is expected to continue.

However, the new standards of performance which became effective in 1974 limit the emissions from fluid catalytic crackers (Ref. 5-16). The promulgated standards apply to PART and CO emissions from new or modified catalyst regenerators. Essentially, an operator is prohibited from discharging (1) PART matter in excess of 1 kg/1000 kg (1 lb/1000 lb) of coke burnoff in the catalyst regenerator and (2) gases which contain CO in excess of 0.050 percent by volume (500 parts per million).

Background information contained in Refs. 5-21 and 5-22 shows that compliance with the new standards may be achieved by use of more than one type of control technique. Emissions of CO from fluid cracking regenerators are also discussed in Ref. 5-20.

Since the regulations apply to new plants and existing plants which were modified in a way that increased their emissions, it became necessary to assess the expected degree of modernization which can occur between the present and 1980. In other words, to forecast the emissions one must evaluate the expected rapidity of plant replacement and the fraction of controlled emission production levels which would be in effect. Information concerning refinery abandonments, replacements, enlargement, and modernization is scarce. As reported by Nelson (Ref. 5-23), a refinery that is to operate profitably must adhere to certain rules:

a. Grow in crude capacity so that the refiner retains his share of the growing market

b. Be constantly repaired and maintained

c. Grow in downstream technology to meet product and quality requirements

d. Grow technologically so that it remains competitive

Thus, not only does crude and downstream capacity increase, but whole process units (e.g., crude, cracking, and reforming) are replaced from time to time so that the larger refinery is not simply an accumulation of small units. It has also been shown that on average a refinery can be kept competitive with respect to crude capacity and downstream facilities by doubling every 12 to 13 years, or at an annual rate of 5.7 percent. In addition, during recent years, nonoperating refineries of major companies have been below 0.4 percent of existing capacity. The approach taken was to assume that these criteria apply also to fluid catalytic cracking, and on this basis an analytical assessment was made to forecast charge rates.

5.5.3 Moving Bed Cracking

This form of catalytic cracking appears to be of diminishing importance in terms of overall charge rates. Recent trends according to Ref. 5-15 show that daily capacity receded from 0.5×10^6 bbl/day in 1972 to 0.3×10^6 bbl/day in 1975. At this rate of decline (roughly 16 percent annually), the daily charge rate would be about 0.13×10^6 bbl/day, but it is not known how the new regulations will affect refiners plans. The approach used was to assume the decline would continue at approximately half this rate so that by 1980 the daily throughput would be 0.2×10^6 bbl/day. The annual charge rate becomes 0.07×10^9 bbl/year or 0.07×10^6 SCC/year. The uncertainty in charge rate is thus relatively high. The emission factors used were those in Ref. 5-1.

5.5.4 Coking and Miscellaneous Categories

These categories include particulate dispersions resulting from coke making and various other HC losses. No special approach was necessary for SCCs based upon total annual charge rate. For coking, annual charge rates were based on the assumption that two percent of capacity is used in coke making. According to Ref. 5-3, coke capacity of 43,410 tons is obtained from a daily feed capacity of 14.2 × 10^6 bbl. At 300 lb/bbl, we obtain

$$\frac{43,410 \text{ ton/day}}{14.216 \times 10^6 \text{ bbl/day} \times 300 \text{ lb/bbl} \times \frac{\text{ton}}{2000 \text{ lb}}} \times 100 = 2.0\%$$

5.6 RESULTS AND DISCUSSION

Tables 5-2-a and 5-3-a summarize the results of the inventory studies for process heaters, catalytic cracking, and the miscellaneous categories of fluid coking and equipment leakage.

Emission factor levels are generally found to be declining gradually. This is expected to result from higher monetary values for fuel and more stringent control of emissions through expansion and modernization. The new ruling especially in regard to fluid catalytic cracking is estimated to affect 0.67 × 10^9 bbl/year of fresh feed charge rates out of a total of 1.77 × 10^9 bbl/year by 1982. In other words, of the current 1.58 x 10^9, nearly one third of the total charge will either have been replaced or modernized and will therefore be in compliance.

However, as seen in Tables 5-2-b and 5-3-b, large uncertainties can exist in charge rate data, emissions, and other data. It is therefore necessary to periodically review industry production trends, technology achievements, and consumer demands which can impact the resulting year-to-year data.

It was originally intended to compare emission level results from the NEDS data. However, because of significant discrepancies found in the past, this was not attempted here. The most recent NEDS data error showed that total annual charge rate in fluid catalytic cracking was approximately a factor of 20 too high (Ref. 5-24). This error was acknowledged and corrected in Ref. 5-25.

5.7 PETROLEUM REFINERY PRACTICES

5.7.1 Background

Familiarization with overall refinery technology (Ref. 5-23) is prerequisite to understanding the refinery industry practices which constitute important sources of atmospheric emissions. The raw feedstocks, consisting mainly of crude oil but including, also, natural gas and asphalt, are subjected to thermal or chemical treatments leading to a broad variety of intermediate and finished products.

A single refinery may not produce all petroleum products, even in the most diverse of the major composite refineries. Significant differences occur in chemical composition and physical properties of the crude liquid feedstocks that are available to an individual plant. For example, some crudes are highly amenable to the economical production of lubricants and waxes, whereas others may be less so. The fundamental determinant defining which products will be produced at a given refinery is economics. Economics includes not only such factors as equipment capitalization, operating costs, and product values, but also feedstock costs and variability.

5.7.2 Refinery Processing Overview

It is desirable to recognize certain types of similar refinery processes and operations from a chemical engineering aspect. The more important manufacturing procedures that may be associated with atmospheric emissions are identified as follows:

a. Topping
b. Crude distillation
c. Gasoline stabilization
d. Vacuum flash operation
e. Cracking (thermal and catalytic)
f. Catalytic reforming
g. Hydroprocessing
h. Alkylation
i. Isomerization

Topping

The basic operation in all refineries is atmospheric pressure distillation. This operation, known as topping, represents the first step in the fractionation of crude oil feedstock into various boiling range components such as gasoline, kerosene, distillates, lubricants, and fuels. Crude-oil distillation normally requires preheating the feedstock in a heat exchanger train and/or direct-fired heaters before being fed to the distillation tower units. The overhead stream condensate (raw straight-run gasoline) goes to a stabilizer column for propane-butane removal, yielding stabilized straight-run gasoline for later treatment and octane upgrading. The side streams, which boil at intermediate temperatures, yield naphtha, kerosene, diesel oil, and gas oil. The bottom stream, also called reduced crude, may be vacuum-fractionated for lube manufacture or run (with gas oil) into cracking units for conversion into lower molecular weight products, particularly gasoline.

Cracking

The major forms of cracking are thermal and catalytic processes. At one time during World War II, overall gasoline yield from crude was less than 40 percent, and thermal cracking accounted for more than 20 percent of total gasoline yield from crude. Thermal processes are now mainly used for viscosity breaking (visbreaking) of reduced crudes and for coke production. Catalytic cracking is used mostly with gas oil but may sometimes be used on various fractions, including naphtha and residuals. The process takes one of several forms, depending upon the method of handling the catalyst. Fluidized bed catalytic cracking represents the largest overall capacity in the United States, followed by Thermofor and Houdriflow moving bed processes. Cracking causes decomposition of the higher molecular weight constituents of petroleum, which produces products in lower boiling ranges. These include large amounts of olefinic gases, gasoline, and recycle oil. Coincident with the disintegration mechanisms, coke deposits on the catalyst. The amount and rate of coke formation varies with the type of feed and catalyst, system design, and operating conditions. Generally, the coking laydown ranges between 4 and 10 percent of the fresh feed charge (Ref. 5-23).

Since catalyst activity declines with coke deposition, reactivation is required and is accomplished by periodic burnoff of the coke with air. Modern systems operate continuously by recirculating finely divided catalyst beads between the reactor and the regenerator. Regenerator off gases contain the usual combustion products of HC, but complete combustion of carbon is seldom accomplished during regeneration. Concentrations of CO in the flue gases, therefore, are also variable but generally 8 to 10 percent by volume. Further combustion of these gases in flares or CO boilers may be accomplished to recover heat energy and to minimize emissions. Cyclone separators are the means used to retain the solids in the circulating system. Additional separation equipment in the form of electrostatic precipitators can be used to further recover catalyst fines.

Recent advances have occurred in fluid catalytic cracking, including the use of highly active zeolitic catalysts, higher pressures and temperatures, more efficient equipment, and improved construction materials. Higher equipment capacities, improved conversion and energy utilization, higher octane products, and greater operating flexibility have resulted. Descriptions of several modern catalytic cracking processes as practiced by major refiners are provided in Ref. 5-26. Considerable study effort was devoted to catalytic cracking practices because of the overall impact of these practices on atmospheric emissions.

Catalytic Reforming

Catalytic reforming causes rearrangement of HC molecules, primarily accompanied by hydrogen abstraction (dehydrogenation) or addition (hydrogenation). The process is used to upgrade low-octane naphtha to high-octane gasolines and to produce aromatics such as benzene, toluene, and xylene (BTX). Reforming was developed in the late 1940s and early 1950s with a platinum catalyst on a ceramic substrate. One of the main advantages of the so-called platforming process at that time was the great improvement in catalyst lifetime relative to existing cracking catalysts. In catalytic cracking, about 10-gal oil/lb catalyst could be processed before regeneration was needed while the reforming processes could treat 1000-gal oil/lb catalyst. By 1956, as much as 10,000-gal oil/lb catalyst could be treated. Other advantages of reforming included resistance to permanent catalyst poisoning, ability to achieve multiple reactions simultaneously (e.g., dehydrogenation, dehydroisomerization, dehydrocyclization, isomerization, and hydrodesulfurization). In short, the process was used to produce a high quality gasoline known as reformate and a high yield of aromatics (for which there existed a high market demand at the time). More recently, catalytic reforming processes have become a valuable source of byproduct hydrogen. As in the case of catalytic cracking, newer catalysts (some including nonnoble materials) are being developed. The processes are variously referred to as platforming, magnaforming, houdriforming, powerforming, rheniforming, and ultraforming (Ref. 5-26).

A particular type of reforming process involving rearrangement of a HC molecular structure is known as isomerization. Originally, isomerization involved the vapor-phase conversion of HC from one structure to another by an acid catalyst (e.g., butane to isobutane, C_4 isomerization; pentane to isopentanes, C_5 isomerization). Now, more modern plants such as Butamer, Penex, and Hysomer process reactants in the presence of highly active and selective fixed-bed noble catalysts. Such plants are often operated in conjunction with alkylation facilities. The clear octane ratings of isomerization products is significantly improved. Unconverted reactants are often recycled.

Hydroprocessing

The rapid increase in catalytic reforming capacity during the past 25 years and the consequent availability of large amounts of hydrogen produced therefrom has stimulated the development of refinery processing in which the low-cost hydrogen is consumed or used within a particular process. The general terms hydroprocessing, hydrotreating, and hydrorefining are used to describe a multitude of production systems. The most usual applications are for desulfurization (also called hydrosulfurization) of various petroleum fractions in which many of the more stable sulfur-containing compounds, such as mercaptans, are destroyed catalytically into HC remnants. The liberated sulfur combines with the hydrogen to form hydrogen sulfide gas which requires removal to avoid emission to the atmosphere. This may be accomplished in several ways, often leading to recovery of marketable byproduct sulfur compounds.

Some of the more commonly known processes are Gulfining, HDS, RDS, VRDS, and ultrasweetening. Besides desulfurization treatments, hydrogen processing includes selective hydrogenation treatment of certain olefin or aromatic stocks and lube oil improvement. Finally, there are combination processes such as ultrafining. A number of hydroprocessing plant descriptions are contained in Ref. 5-26.

Rebuilding Processes

Several processes are used to rebuild various types of low molecular weight of hydrocarbons into higher molecular weight species. Alkylation and polymerization are processes in which unsaturated two-, three-, and four-carbon atom gases are reacted in order to form high-octane branched chain hydrocarbons for gasoline. The olefinic feedstocks are usually cuts obtained from catalytic cracking. When olefins are added to olefins, the product is called polymer gasoline. When an olefin is connected to a saturated molecule such as isobutane, the product is called alkylate. Alkylate finds extensive use in aviation gasoline.

Other Processes

Several other refinery processes were examined but do not appear at this time to be significant factors relating to atmospheric emissions in terms of volatile HC, CO, CO_2, or NO_x except, perhaps, from the standpoint of requiring boiler-produced steam or direct-fired thermal energy. These include the following:

a. Light oil treating
b. Lube oil processing

c. Asphalt manufacture
d. Sulfur recovery
e. Wax forming operations

Coking processes involve relatively severe cracking for converting heavy components (such as pitch and tar) into lighter products (such as gas oil and coke) for fuel and other specialty uses. Two major processes are delayed coking and fluid coking, the latter being a continuous fluidized bed circulation flow process. In withdrawing the coke product from the system, some entrainment of particulates does occur as the gases pass through the cyclone separators and disperse to the atmosphere.

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SECTION VI

POINT SOURCE EVAPORATION

6.1 INTRODUCTION

The point source evaporation category of stationary source emissions is comprised of activities involving cleaning solvents, surface coatings, and the storage and marketing transportation of petroleum products. The emissions of concern are hydrocarbons (HC), which are approximately 99 percent of all point source evaporative emissions.

Forty-nine Source Classification Code (SCC) categories were identified from Ref. 6-1 which emitted 500 tons per year or more of pollutant. These point source emission categories formed the list of activities studied in the HC evaporation category. For better identification of the nature of HC emissions from evaporation, many of the 49 SCCs were subdivided to yield a total of 85 processes, which were identified as modified SCCs (MSCC) categories.

6.2 SUMMARY

The total HC evaporation rate from point sources in 1977 was 3.84-million tons/year and is estimated to drop by 40 percent to 2.3-million tons/year in 1982.

The largest contributor to these totals is the paint and surface coating application industries. The most dramatic reduction in estimated emissions for the years of interest occurs in the petroleum products storage category. The reduction is estimated to be 1.15-million tons/year (1.65 to 0.50) or a minus 70 percent change in the 5-year period. This reduction is based on an assumed elimination of the use of fixed-roof tanks for the storage of the most volatile products (gasoline and crude oil).

Table 6-1 presents the MSCC number, description, and charge rate unit for the point source evaporation categories studied. A detailed list of emissions for the two selected years from evaporation and total annual charge rates (TACRP) is shown in Tables 6-2-a and 6-3-a and their uncertainties in Tables 6-2-b and 6-3-b.

6.3 PROCESSES EVALUATED

According to the National Emissions Data System (NEDS) (Ref. 6-2), 4.5-million tons of HC vapor are annually evaporated into the atmosphere from stationary point sources. This represents 58 percent of the total (evaporation plus combustion) point source HC emissions and 40 percent of the total (point plus area) stationary source HC emissions. In addition to the 4.5-million tons/year of HC from point source evaporation, Ref. 6-2 lists another 2.75-million tons/year of HC from area source evaporation. (A point source is identified as more than or equal to 100 tons/year; an area source is less than this amount.) Except for HC evaporation from handling gasoline at retail outlets (filling stations), no consideration was given to area source emissions. This section presents discussions of the processes that produce stationary source HC evaporative emission.

6.3.1 Cleaning Solvents

Cleaning solvents are broadly divided into two application categories: (1) dry cleaning of clothing and (2) degreasing of metal and other parts.

The emissions from cleaning solvents represent only about 3 percent of total point source evaporation. Petroleum (Stoddard) and chlorinated synthetic (Perchlorethylene) solvents are used for both applications where trichlorethane, trichloroethylene, and methylene chloride are used only for degreasing operations. Although the petroleum-based solvent is considered the most attractive from a low pollution standpoint, because it is not photochemically reactive, its production rate is on the decline. It is

(Continued on page 6-39)

Table 6-1. DEFINITION OF HC EVAPORATION

MSCC	Source Category	Charge Rate Unit
401001010	Perchlorethylene dry cleaning	Clothes, tons/yr
401001020	Stoddard dry cleaning	Clothes, tons/yr
401002010	Stoddard degreasing solvent	Solvent, tons/yr
401002020	Trichleroethane degreasing solvent	Solvent, tons/yr
401002030	Perchloroethylene degreasing solvent	Solvent, tons/yr
401002050	Trichloroethylene degreasing solvent	Solvent, tons/yr
401002990	Miscellaneous degreasing solvent	Solvent, tons/yr
402001011	Sheet, strip, and coil paint	Paint, tons/yr
402001012	Auto and truck paint	Paint, tons/yr
402001013	Major appliances paint	Paint, tons/yr
402001014	Industrial machinery paint	Paint, tons/yr
402001015	Wooden furniture paint	Paint, tons/yr
402001016	Metal furniture paint	Paint, tons/yr
402001017	Small appliances paint	Paint, tons/yr
402001018	Farm machinery paint	Paint, tons/yr
402001019	Commercial machinery paint	Paint, tons/yr
402002011	Coating for coated paper	Coating, tons/yr
402002012	Coating for folding cartons	Coating, tons/yr
402002013	Coating for kraft paper	Coating, tons/yr
402002014	Coating for milk cartons	Coating, tons/yr
402002015	Coating for paper bags	Coating, tons/yr
402002016	Coating for paper boxes	Coating, tons/yr
402002017	Coating for paper tubes and cans	Coating, tons/yr
402002018	Coating for printing paper	Coating, tons/yr
402002019	Coating for waxed paper	Coating, tons/yr

Table 6-1. DEFINITION OF HC EVAPORATION (Continued)

MSCC	Source Category	Charge Rate Unit
402003011	Varnish and shellac on sheet, strip, and coil	Coating, tons/yr
402003013	Varnish and shellac on major appliances	Coating, tons/yr
402003014	Varnish and shellac on industrial machinery	Coating, tons/yr
402003017	Varnish and shellac on small appliances	Coating, tons/yr
402003019	Varnish and shellac on commercial machinery	Coating, tons/yr
402004011	Lacquer on sheet, strip, and coil	Coating, tons/yr
402004012	Lacquer on autos and trucks	Coating, tons/yr
402004015	Lacquer on wooden furniture	Coating, tons/yr
402004017	Lacquer on small appliances	Coating, tons/yr
402005011	Enamel on sheet, strip, and coil	Coating, tons/yr
402005012	Enamel on autos and trucks	Coating, tons/yr
402005013	Enamel on major appliances	Coating, tons/yr
402005016	Enamel on metal furniture	Coating, tons/yr
402005017	Enamel on small appliances	Coating, tons/yr
402006011	Primer on sheet, strip, and coil	Coating, tons/yr
402006012	Primer on autos and trucks	Coating, tons/yr
402006014	Primer on industrial machinery	Coating, tons/yr
402006016	Primer on metal furniture	Coating, tons/yr
402006017	Primer on small appliances	Coating, tons/yr
402006019	Primer on commercial furniture	Coating, tons/yr
402007011	Dye for fabric	Solution, tons/yr
402007012	Permanent crispness solution for fabric	Solution, tons/yr
402007013	Sizing solution for fabric	Solution, tons/yr

Table 6-1. DEFINITION OF HC EVAPORATION (Continued)

MSCC	Source Category	Charge Rate Unit
402007014	Waterproof solution for fabric	Solution, tons/yr
402007015	Wrinkle resistance solution for fabric	Solution, tons/yr
402008011	Oven coating for sheet, strip, and coil	Coating, tons/yr
402008012	Oven coating for autos and trucks	Coating, tons/yr
402999990	Miscellaneous surface coating activity	Coating, tons/yr
403001011	Fixed-roof tank gasoline breathing loss	Storage capacity, 1000 gal
403001021	Fixed-roof tank crude breathing loss	Storage capacity, 1000 gal
403001031	Fixed-roof tank gasoline working loss	Throughput, 1000 gal/yr
403001041	Fixed-roof tank crude working loss	Throughput, 1000 gal/yr
403001051	Fixed-roof tank JP-4 breathing loss loss	Storage capacity, 1000 gal
403001061	Fixed-roof tank kerosene breathing loss	Storage capacity, 1000 gal
403001071	Fixed-roof tank distillate breathing loss	Storage capacity, 1000 gal
403001501	Fixed-roof tank JP-4 working loss	Throughput, 1000 gal/yr
403001511	Fixed-roof tank kerosene working loss	Throughput, 1000 gal/yr
403001521	Fixed-roof tank distillate working loss	Throughput, 1000 gal/yr
403002011	Floating-roof gasoline tank standing loss	Storage capacity, 1000 gal
403002021	Floating-roof gasoline tank working loss	Throughput, 1000 gal/yr
403002031	Floating-roof crude tank standing loss	Storage capacity, 1000 gal

Table 6-1. DEFINITION OF HC EVAPORATION (Continued)

MSCC	Source Category	Charge Rate Unit
403002041	Floating-roof crude tank working loss	Throughput, 1000 gal/yr
403002051	Floating-roof JP-4 tank standing loss	Throughput, 1000 gal/yr
403002061	Floating-roof kerosene standing loss	Storage capacity, 1000 gal
403002071	Floating-roof distillate standing loss	Storage capacity, 1000 gal
403003020	Variable vapor-space gasoline working loss	Throughput, 1000 gal/yr
403999990	Miscellaneous petroleum product storage loss	Stored, 1000 gal
406001011	Load gasoline on tank cars, splash	Transferred, 1000 gal/yr
406001012	Load gasoline on tank trucks, splash	Transferred, 1000 gal/yr
406001021	Load crude on tank cars, splash	Transferred,
406001022	Load crude on trucks, splash	Transferred,
406001261	Load gasoline on tank cars, submerge	Transferred, 1000 gal/yr
406001262	Load gasoline on tank trucks, submerge	Transferred, 1000 gal/yr
406001271	Load crude on tank cars, submerge	Transferred, 1000 gal/yr
406002010	Load gasoline onto marine vessels	Transferred,
406002260	Unload gasoline from marine vessels	Transferred, 1000 gal/yr
406002270	Unload crude from marine vessels	Transferred, 1000 gal/yr

Table 6-2-a. 1977 HC EVAPORATION EMISSIONS AND CHARGE RATES

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                               HYDROCARBON EVAPORATION                          PAGE  1
ANNUAL CHARGE RATES AND EMISSIONS PROJECTED TO 1977     RUN DATE= NOV 16,1977
   MODIFIED          TACRF              EMISSIONS (MILLIONS OF TONS / YEAR)
     SCC          (SCC UNITS)          NOX          HC          CO          PART

 401001000            42080.           NEG         .003         NEG          NEG

 401001010            31650.           NEG         .002         NEG          NEG
 401001020            10430.           NEG         .002         NEG          NEG

 401002000           114480.           NEG         .103         NEG          NEG

 401002010              880.           NEG         .001         NEG          NEG
 401002020             3070.           NEG         .003         NEG          NEG
 401002030             8613.           NEG         .007         NEG          NEG
 401002050             4470.           NEG         .004         NEG          NEG
 401002990            97450.           NEG         .088         NEG          NEG

 401999000           118650.           NEG         .023         NEG          NEG

 401999990           118650.           NEG         .023         NEG          NEG

 402001000           470730.           NEG         .215         NEG          NEG

 402001010           470730.           NEG         .215         NEG          NEG

 402001011           340000.           NEG         .171         NEG          NEG
 402001012            87000.           NEG         .029         NEG          NEG
 402001013            10240.           NEG         .003         NEG          NEG
 402001014             7200.           NEG         .002         NEG          NEG
 402001015            10990.           NEG         .004         NEG          NEG
 402001016             8135.           NEG         .003         NEG          NEG
 402001017             2325.           NEG         .001         NEG          NEG
 402001018             3370.           NEG         .001         NEG          NEG
 402001019             1466.           NEG         .000         NEG          NEG


 402002000          9437500.           NEG         .411         NEG          NEG

 402002010          9437500.           NEG         .411         NEG          NEG

 402002011           122650.           NEG         .056         NEG          NEG
 402002012            19650.           NEG         .004         NEG          NEG
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Table 6-2-a. 1977 HC EVAPORATION EMISSIONS AND CHARGE RATES (Continued)

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                            HYDROCARBON EVAPORATION                          PAGE  2
ANNUAL CHARGE RATES AND EMISSIONS PROJECTED TO 1977     RUN DATE= NOV 16,1977
  MODIFIED           TACRE                EMISSIONS (MILLIONS OF TONS / YEAR)
    SCC           (SCC UNITS)        NOX            HC            CO           PART

 402002013           134300.          NEG          .058          NEG           NEG
 402002014            26050.          NEG          .023          NEG           NEG
 402002015          8665000.          NEG          .182          NEG           NEG
 402002016            69350.          NEG          .013          NEG           NEG
 402002017             5620.          NEG          .001          NEG           NEG
 402002018            71900.          NEG          .041          NEG           NEG
 402002019           303100.          NEG          .030          NEG           NEG

 402003000           299730.          NEG          .178          NEG           NEG

 402003010           299730.          NEG          .178          NEG           NEG

 402003011           290000.          NEG          .172          NEG           NEG
 402003013             8800.          NEG          .005          NEG           NEG
 402003014              481.          NEG          .000          NEG           NEG
 402003017              348.          NEG          .000          NEG           NEG
 402003019               98.          NEG          .000          NEG           NEG

 402004000            80186.          NEG          .053          NEG           NEG

 402004010            80186.          NEG          .053          NEG           NEG

 402004011            32800.          NEG          .022          NEG           NEG
 402004012            43200.          NEG          .029          NEG           NEG
 402004015             4130.          NEG          .003          NEG           NEG
 402004017               56.          NEG          .000          NEG           NEG

 402005000           315150.          NEG          .163          NEG           NEG

 402005010           315150.          NEG          .163          NEG           NEG

 402005011           130500.          NEG          .067          NEG           NEG
 402005012           172800.          NEG          .089          NEG           NEG
 402005013            11350.          NEG          .007          NEG           NEG
 402005016              239.          NEG          .000          NEG           NEG
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Table 6-2-a. 1977 HC EVAPORATION EMISSIONS AND CHARGE RATES (Continued)

HYDROCARBON EVAPORATION PAGE 3

ANNUAL CHARGE RATES AND EMISSIONS PROJECTED TO 1977 RUN DATE= NOV 16,1977

MODIFIED SCC	TACRF (SCC UNITS)	EMISSIONS (MILLIONS OF TONS / YEAR) NOX	HC	CO	PART
402005017	256.	NEG	.000	NEG	NEG
402006000	959730.	NEG	.461	NEG	NEG
402006010	959730.	NEG	.461	NEG	NEG
402006011	933000.	NEG	.448	NEG	NEG
402006012	21600.	NEG	.010	NEG	NEG
402006014	460.	NEG	.000	NEG	NEG
402006016	4243.	NEG	.002	NEG	NEG
402006017	333.	NEG	.000	NEG	NEG
402006019	94.	NEG	.000	NEG	NEG
402007000	1597500.	NEG	.231	NEG	NEG
402007010	1597500.	NEG	.231	NEG	NEG
402007011	337500.	NEG	.219	NEG	NEG
402007012	272.	NEG	.000	NEG	NEG
402007013	1066000.	NEG	.011	NEG	NEG
402007014	10765.	NEG	.000	NEG	NEG
402007015	183000.	NEG	.001	NEG	NEG
402008000	180700.	NEG	.099	NEG	NEG
402008010	180700.	NEG	.099	NEG	NEG
402008011	72700.	NEG	.040	NEG	NEG
402008012	108000.	NEG	.059	NEG	NEG
402999000	1539400.	NEG	.192	NEG	.011
402999990	1539400.	NEG	.192	NEG	.011

Table 6-2-a. 1977 HC EVAPORATION EMISSIONS AND CHARGE RATES (Continued)

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                                   HYDROCARBON EVAPORATION                              PAGE  4
ANNUAL CHARGE RATES AND EMISSIONS PROJECTED TO 1977      RUN DATE= NOV 16,1977
  MODIFIED          TACRP                    EMISSIONS (MILLIONS OF TONS / YEAR)
    SCC          (SCC UNITS)           NOX              HC              CO              PART
 403001000                              NEG            1.007            NEG              NEG
 403001010         12800000.            NEG             .666            NEG              NEG
 403001011         12800000.            NEG             .666            NEG              NEG
 403001020          1120000.            NEG             .033            NEG              NEG
 403001021          1120000.            NEG             .033            NEG              NEG
 403001030         32000000.            NEG             .166            NEG              NEG
 403001031         32000000.            NEG             .166            NEG              NEG
 403001040         13800000.            NEG             .062            NEG              NEG
 403001041         13800000.            NEG             .062            NEG              NEG
 403001050           124000.            NEG             .002            NEG              NEG
 403001051           124000.            NEG             .002            NEG              NEG
 403001060           500000.            NEG             .004            NEG              NEG
 403001061           500000.            NEG             .004            NEG              NEG
 403001070          6914100.            NEG             .050            NEG              NEG
 403001071          6914100.            NEG             .050            NEG              NEG
 403001500         49170000.            NEG             .025            NEG              NEG
 403001501          1570000.            NEG             .002            NEG              NEG
 403001510         20800000.            NEG             .010            NEG              NEG
 403001511         20800000.            NEG             .010            NEG              NEG
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Table 6-2-a. 1977 HC EVAPORATION EMISSIONS AND CHARGE RATES (Continued)

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                          HYDROCARBON EVAPORATION                            PAGE  5
ANNUAL CHARGE RATES AND EMISSIONS PROJECTED TO 1977      RUN DATE= NOV 16,1977
 MODIFIED      TACRF                EMISSIONS (MILLIONS OF TONS / YEAR)
   SCC       (SCC UNITS)       NOX            HC            CO           PART
403001520     26800000.        NEG           .013          NEG           NEG
403001521     26800000.        NEG           .013          NEG           NEG

403002000                      NEG           .194          NEG           NEG
403002010      6920000.        NEG           .046          NEG           NEG
403002011      6920000.        NEG           .046          NEG           NEG
403002020      1900000.        NEG           .003          NEG           NEG
403002021      1900000.        NEG           .003          NEG           NEG
403002030     11140000.        NEG           .059          NEG           NEG
403002031     11140000.        NEG           .059          NEG           NEG
403002040     55000000.        NEG           .086          NEG           NEG
403002041     55000000.        NEG           .086          NEG           NEG
403002050        89700.        NEG           .000          NEG           NEG
403002051        89700.        NEG           .000          NEG           NEG
403002060        52000.        NEG           .000          NEG           NEG
403002061        52000.        NEG           .000          NEG           NEG
403002070       154000.        NEG           .000          NEG           NEG
403002071       154000.        NEG           .000          NEG           NEG

403003000     18360000.        NEG           .081          NEG           NEG
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Table 6-2-a. 1977 HC EVAPORATION EMISSIONS AND CHARGE RATES (Continued)

HYDROCARBON EVAPORATION PAGE 6

ANNUAL CHARGE RATES AND EMISSIONS PROJECTED TO 1977 RUN DATE= NOV 16,1977

MODIFIED SCC	TACRF (SCC UNITS)	EMISSIONS (MILLIONS OF TONS / YEAR) NOX	HC	CO	PART
403003020	18360000.	NEG	.081	NEG	NEG
403999070	15000000.	NEG	.069	NEG	NEG
403999990	15000000.	NEG	.069	NEG	NEG
406001000	82194000.	NEG	.210	NEG	NEG
406001010	19971000.	NEG	.124	NEG	NEG
406001011	71000.	NEG	.000	NEG	NEG
406001012	19900000.	NEG	.123	NEG	NEG
406001020	2486000.	NEG	.013	NEG	NEG
406001021	56000.	NEG	.000	NEG	NEG
406001022	2430000.	NEG	.013	NEG	NEG
406001260	46577000.	NEG	.057	NEG	NEG
406001261	77000.	NEG	.000	NEG	NEG
406001262	46500000.	NEG	.057	NEG	NEG
406001270	13160000.	NEG	.016	NEG	NEG
406001271	360000.	NEG	.000	NEG	NEG
406001272	12800000.	NEG	.015	NEG	NEG
406002000	117600000.	NEG	.147	NEG	NEG
406002010	18300000.	NEG	.016	NEG	NEG
406002020	11000000.	NEG	.008	NEG	NEG
406002260	18300000.	NEG	.012	NEG	NEG
406002270	70000000.	NEG	.112	NEG	NEG

Table 6-2-b. 1977 HC EVAPORATION UNCERTAINTIES

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                                HYDROCARBON EVAPORATION                              PAGE  1
TACP AND EMISSION UNCERTAINTIES PROJECTED TO 1977        RUN DATE= NOV 16,1977
 MODIFIED          TACRF                      EMISSIONS (MILLIONS OF TONS / YEAR)
   SCC          (SCC UNITS)          NOX                  HC            CO             PART

401001000    +     25004.            NEG         +   .004          NEG            NEG
             -     15296.            NEG         -   .002          NEG            NEG

401001010    +     11189.            NEG         +   .002          NEG            NEG
             -     11189.            NEG         -   .001          NEG            NEG
401001020    +     22360.            NEG         +   .003          NEG            NEG
             -     10430.            NEG         -   .002          NEG            NEG

401002000    +     60930.            NEG         +   .058          NEG            NEG
             -     60930.            NEG         -   .059          NEG            NEG

401002010    +       531.            NEG         +   .000          NEG            NEG
             -       531.            NEG         -   .000          NEG            NEG
401002020    +      1118.            NEG         +   .001          NEG            NEG
             -      1118.            NEG         -   .001          NEG            NEG
401002030    +      2816.            NEG         +   .003          NEG            NEG
             -      2816.            NEG         -   .003          NEG            NEG
401002050    +      1746.            NEG         +   .002          NEG            NEG
             -      1746.            NEG         -   .002          NEG            NEG
401002990    +     60827.            NEG         +   .058          NEG            NEG
             -     60827.            NEG         -   .059          NEG            NEG

401999000    +     20907.            NEG         +   .005          NEG            NEG
             -     20907.            NEG         -   .005          NEG            NEG

401999990    +     20907.            NEG         +   .005          NEG            NEG
             -     20907.            NEG         -   .005          NEG            NEG

402001000    +     45946.            NEG         +   .036          NEG            NEG
             -     45946.            NEG         -   .036          NEG            NEG

402001010    +     45946.            NEG         +   .036          NEG            NEG
             -     45946.            NEG         -   .036          NEG            NEG

402001011    +     37646.            NEG         +   .029          NEG            NEG
             -     37646.            NEG         -   .029          NEG            NEG
402001012    +     26016.            NEG         +   .022          NEG            NEG
             -     26016.            NEG         -   .022          NEG            NEG
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Table 6-2-b. 1977 HC EVAPORATION UNCERTAINTIES (Continued)

HYDROCARBON EVAPORATION PAGE 2

TACF AND EMISSION UNCERTAINTIES PROJECTED TO 1977 RUN DATE= NOV 16,1977

MODIFIED SCC		TACRF (SCC UNITS)	NOX		EMISSIONS (MILLIONS OF TONS / YEAR) HC	CO	PART
402001013	+	1874.	NEG	+	.002	NEG	NEG
	-	1874.	NEG	-	.002	NEG	NEG
402001014	+	1637.	NEG	+	.002	NEG	NEG
	-	1637.	NEG	-	.002	NEG	NEG
402001015	+	2752.	NEG	+	.003	NEG	NEG
	-	2752.	NEG	-	.003	NEG	NEG
402001016	+	1670.	NEG	+	.002	NEG	NEG
	-	1670.	NEG	-	.002	NEG	NEG
402001017	+	241.	NEG	+	.001	NEG	NEG
	-	241.	NEG	-	.001	NEG	NEG
402001018	+	608.	NEG	+	.001	NEG	NEG
	-	608.	NEG	-	.001	NEG	NEG
402001019	+	198.	NEG	+	.000	NEG	NEG
	-	198.	NEG	-	.000	NEG	NEG
402002000	+	3922000.	NEG	+	.217	NEG	NEG
	-	3893700.	NEG	-	.189	NEG	NEG
402002010	+	3922000.	NEG	+	.217	NEG	NEG
	-	3893700.	NEG	-	.189	NEG	NEG
402002011	+	54708.	NEG	+	.026	NEG	NEG
	-	54708.	NEG	-	.026	NEG	NEG
402002012	+	8775.	NEG	+	.002	NEG	NEG
	-	8775.	NEG	-	.002	NEG	NEG
402002013	+	59896.	NEG	+	.027	NEG	NEG
	-	59896.	NEG	-	.027	NEG	NEG
402002014	+	11621.	NEG	+	.011	NEG	NEG
	-	11621.	NEG	-	.011	NEG	NEG
402002015	+	3889700.	NEG	+	.192	NEG	NEG
	-	3889700.	NEG	-	.182	NEG	NEG
402002016	+	475110.	NEG	+	.090	NEG	NEG
	-	69350.	NEG	-	.013	NEG	NEG
402002017	+	2515.	NEG	+	.001	NEG	NEG
	-	2515.	NEG	-	.001	NEG	NEG
402002018	+	32145.	NEG	+	.019	NEG	NEG
	-	32145.	NEG	-	.019	NEG	NEG

Table 6-2-b. 1977 HC EVAPORATION UNCERTAINTIES (Continued)

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                                   HYDROCARBON EVAPORATION                          PAGE   3
TACR AND EMISSION UNCERTAINTIES PROJECTED TO 1977          RUN DATE= NOV 16,1977
 MODIFIED           TACRF                     EMISSIONS (MILLIONS OF TONS / YEAR)
   SCC           (SCC UNITS)          NOX                HC             CO            PART
402002019    +      135190.           NEG        +     .014            NEG            NEG
             -      135190.           NEG        -     .014            NEG            NEG

402003000    +       31425.           NEG        +     .027            NEG            NEG
             -       31425.           NEG        -     .027            NEG            NEG

402003010    +       31425.           NEG        +     .027            NEG            NEG
             -       31425.           NEG        -     .027            NEG            NEG

402003011    +       31384.           NEG        +     .027            NEG            NEG
             -       31384.           NEG        -     .027            NEG            NEG
402003013    +        1591.           NEG        +     .001            NEG            NEG
             -        1591.           NEG        -     .001            NEG            NEG
402003014    +         109.           NEG        +     .000            NEG            NEG
             -         109.           NEG        -     .000            NEG            NEG
402003017    +          36.           NEG        +     .000            NEG            NEG
             -          36.           NEG        -     .000            NEG            NEG
402003019    +          88.           NEG        +     .000            NEG            NEG
             -          88.           NEG        -     .000            NEG            NEG

402004000    +       13532.           NEG        +     .011            NEG            NEG
             -       13532.           NEG        -     .011            NEG            NEG

402004010    +       13532.           NEG        +     .011            NEG            NEG
             -       13532.           NEG        -     .011            NEG            NEG

402004011    +        3584.           NEG        +     .005            NEG            NEG
             -        3584.           NEG        -     .005            NEG            NEG
402004012    +       13008.           NEG        +     .010            NEG            NEG
             -       13008.           NEG        -     .010            NEG            NEG
402004015    +        1034.           NEG        +     .001            NEG            NEG
             -        1034.           NEG        -     .001            NEG            NEG
402004017    +           5.           NEG        +     .000            NEG            NEG
             -           5.           NEG        -     .000            NEG            NEG
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Table 6-2-b. 1977 HC EVAPORATION UNCERTAINTIES (Continued)

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                                 HYDROCARBON EVAPORATION                            PAGE  4
TACR AND EMISSION UNCERTAINTIES PROJECTED TO 1977         RUN DATE= NOV 16.1977
 MODIFIED         TACRF                    EMISSIONS (MILLIONS OF TONS / YEAR)
   SCC         (SCC UNITS)           NOX                HC              CO               PART

402005000   +        53907.          NEG        +    .031            NEG              NEG
            -        53907.          NEG        -    .031            NEG              NEG

402005010   +        53907.          NEG        +    .031            NEG              NEG
            -        53907.          NEG        -    .031            NEG              NEG

402005011   +        14346.          NEG        +    .011            NEG              NEG
            -        14346.          NEG        -    .011            NEG              NEG
402005012   +        51923.          NEG        +    .029            NEG              NEG
            -        51923.          NEG        -    .029            NEG              NEG
402005013   +         2051.          NEG        +    .002            NEG              NEG
            -         2051.          NEG        -    .002            NEG              NEG
402005016   +           49.          NEG        +    .000            NEG              NEG
            -           49.          NEG        -    .000            NEG              NEG
402005017   +           26.          NEG        +    .000            NEG              NEG
            -           26.          NEG        -    .000            NEG              NEG

402006000   +       102430.          NEG        +    .113            NEG              NEG
            -       102430.          NEG        -    .113            NEG              NEG

402006010   +       102430.          NEG        +    .113            NEG              NEG
            -       102430.          NEG        -    .113            NEG              NEG

402006011   +       102220.          NEG        +    .113            NEG              NEG
            -       102220.          NEG        -    .113            NEG              NEG
402006012   +         6552.          NEG        +    .004            NEG              NEG
            -         6552.          NEG        -    .004            NEG              NEG
402006014   +          105.          NEG        +    .000            NEG              NEG
            -          105.          NEG        -    .000            NEG              NEG
402006016   +          874.          NEG        +    .001            NEG              NEG
            -          874.          NEG        -    .001            NEG              NEG
402006017   +           36.          NEG        +    .000            NEG              NEG
            -           36.          NEG        -    .000            NEG              NEG
402006019   +           12.          NEG        +    .000            NEG              NEG
            -           12.          NEG        -    .000            NEG              NEG
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Table 6-2-b. 1977 HC EVAPORATION UNCERTAINTIES (Continued)

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                        HYDROCARBON EVAPORATION                                  PAGE  5
TACR AND EMISSION UNCERTAINTIES PROJECTED TO 1977        RUN DATE= NOV 16,1977
 MODIFIED          TACRF                    EMISSIONS (MILLIONS OF TONS / YEAR)
   SCC          (SCC UNITS)          NOX               HC           CO          PART

402007000    +    106670.            NEG          +   .120         NEG           NEG
             -    106670.            NEG          -   .122         NEG           NEG

402007010    +    106670.            NEG          +   .120         NEG           NEG
             -    106670.            NEG          -   .122         NEG           NEG

402007011    +     32039.            NEG          +   .120         NEG           NEG
             -     32039.            NEG          -   .122         NEG           NEG
402007012    +        26.            NEG          +   .000         NEG           NEG
             -        26.            NEG          -   .000         NEG           NEG
402007013    +    100130.            NEG          +   .001         NEG           NEG
             -    100130.            NEG          -   .002         NEG           NEG
402007014    +      1001.            NEG          +   .001         NEG           NEG
             -      1001.            NEG          -   .000         NEG           NEG
402007015    +     18021.            NEG          +   .000         NEG           NEG
             -     18021.            NEG          -   .000         NEG           NEG

402008000    +     33707.            NEG          +   .021         NEG           NEG
             -     33707.            NEG          -   .021         NEG           NEG

402008010    +     33707.            NEG          +   .021         NEG           NEG
             -     33707.            NEG          -   .021         NEG           NEG

402008011    +      7932.            NEG          +   .007         NEG           NEG
             -      7932.            NEG          -   .007         NEG           NEG
402008012    +     32760.            NEG          +   .020         NEG           NEG
             -     32760.            NEG          -   .020         NEG           NEG

402999000    +    287690.            NEG          +   .044         NEG       +  .002
             -    287690.            NEG          -   .044         NEG       -  .002

402999990    +    287690.            NEG          +   .044         NEG       +  .002
             -    287690.            NEG          -   .044         NEG       -  .002

403001000                            NEG          +   .425         NEG           NEG
                                     NEG          -   .321         NEG           NEG
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Table 6-2-b. 1977 HC EVAPORATION UNCERTAINTIES (Continued)

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                                  HYDROCARBON EVAPORATION                              PAGE  6
TACR AND EMISSION UNCERTAINTIES PROJECTED TO 1977          RUN DATE= NOV 16,1977
 MODIFIED            TACRF                   EMISSIONS (MILLIONS OF TONS / YEAR)
   SCC            (SCC UNITS)          NOX                  HC            CO            PART
403001010    +      3969900.           NEG         +     .257            NEG            NEG
             -      3969900.           NEG         -     .265            NEG            NEG

403001011    +      3969900.           NEG         +     .257            NEG            NEG
             -      3969900.           NEG         -     .265            NEG            NEG

403001020    +      1216600.           NEG         +     .036            NEG            NEG
             -      1120000.           NEG         -     .033            NEG            NEG

403001021    +      1216600.           NEG         +     .036            NEG            NEG
             -      1120000.           NEG         -     .033            NEG            NEG

403001030    +     60299000.           NEG         +     .313            NEG            NEG
             -     32000000.           NEG         -     .166            NEG            NEG

403001031    +     60299000.           NEG         +     .313            NEG            NEG
             -     32000000.           NEG         -     .166            NEG            NEG

403001040    +     27145000.           NEG         +     .122            NEG            NEG
             -     13800000.           NEG         -     .062            NEG            NEG

403001041    +     27145000.           NEG         +     .122            NEG            NEG
             -     13800000.           NEG         -     .062            NEG            NEG

403001050    +        94339.           NEG         +     .001            NEG            NEG
             -        94339.           NEG         -     .001            NEG            NEG

403001051    +        94339.           NEG         +     .001            NEG            NEG
             -        94339.           NEG         -     .001            NEG            NEG

403001060    +       335410.           NEG         +     .002            NEG            NEG
             -       335410.           NEG         -     .002            NEG            NEG

403001061    +       335410.           NEG         +     .002            NEG            NEG
             -       335410.           NEG         -     .002            NEG            NEG

403001070    +       730820.           NEG         +     .007            NEG            NEG
             -       730820.           NEG         -     .009            NEG            NEG
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Table 6-2-b. 1977 HC EVAPORATION UNCERTAINTIES (Continued)

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                        HYDROCARBON EVAPORATION                              PAGE  7
TACR AND EMISSION UNCERTAINTIES PROJECTED TO 1977        RUN DATE= NOV 16,1977
 MODIFIED          TACRF                 EMISSIONS (MILLIONS OF TONS / YEAR)
   SCC          (SCC UNITS)          NOX              HC          CO          PART

403001071    +      730820.          NEG        +   .007        NEG          NEG
             -      730820.          NEG        -   .009        NEG          NEG

403001500    +    14175000.          NEG        +   .007        NEG          NEG
             -    14175000.          NEG        -   .007        NEG          NEG

403001501    +      960000.          NEG        +   .001        NEG          NEG
             -      960000.          NEG        -   .001        NEG          NEG

403001510    +    10000000.          NEG        +   .005        NEG          NEG
             -    10000000.          NEG        -   .005        NEG          NEG

403001511    +    10000000.          NEG        +   .005        NEG          NEG
             -    10000000.          NEG        -   .005        NEG          NEG

403001520    +    10000000.          NEG        +   .005        NEG          NEG
             -    10000000.          NEG        -   .005        NEG          NEG

403001521    +    10000000.          NEG        +   .005        NEG          NEG
             -    10000000.          NEG        -   .005        NEG          NEG


403002000                            NEG        +   .089        NEG          NEG
                                     NEG        -   .085        NEG          NEG

403002010    +     3133800.          NEG        +   .021        NEG          NEG
             -     3133800.          NEG        -   .022        NEG          NEG

403002011    +     3133800.          NEG        +   .021        NEG          NEG
             -     3133800.          NEG        -   .022        NEG          NEG

403002020    +     7905700.          NEG        +   .011        NEG          NEG
             -     1900000.          NEG        -   .003        NEG          NEG

403002021    +     7905700.          NEG        +   .011        NEG          NEG
             -     1900000.          NEG        -   .003        NEG          NEG
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Table 6-2-b. 1977 HC EVAPORATION UNCERTAINTIES (Continued)

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                         HYDROCARBON EVAPORATION                              PAGE   8
TACR AND EMISSION UNCERTAINTIES PROJECTED TO 1977       RUN DATE= NOV 16,1977
 MODIFIED          TACRP                     EMISSIONS (MILLIONS OF TONS / YEAR)
   SCC          (SCC UNITS)          NOX                 HC             CO           PART
403002030    +    3162300.           NEG          +   .018            NEG           NEG
             -    3162300.           NEG          -   .019            NEG           NEG

403002031    +    3162300.           NEG          +   .018            NEG           NEG
             -    3162300.           NEG          -   .019            NEG           NEG

403002040    +   10198000.           NEG          +   .084            NEG           NEG
             -   10198000.           NEG          -   .080            NEG           NEG

403002041    +   10198000.           NEG          +   .084            NEG           NEG
             -   10198000.           NEG          -   .080            NEG           NEG

403002050    +      54744.           NEG          +   .000            NEG           NEG
             -      54744.           NEG          -   .000            NEG           NEG

403002051    +      54744.           NEG          +   .000            NEG           NEG
             -      54744.           NEG          -   .000            NEG           NEG

403002060    +      20615.           NEG          +   .000            NEG           NEG
             -      20615.           NEG          -   .000            NEG           NEG

403002061    +      20615.           NEG          +   .000            NEG           NEG
             -      20615.           NEG          -   .000            NEG           NEG

403002070    +      61846.           NEG          +   .000            NEG           NEG
             -      61846.           NEG          -   .000            NEG           NEG

403002071    +      61846.           NEG          +   .000            NEG           NEG
             -      61846.           NEG          -   .000            NEG           NEG


403003000    +     458910.           NEG          +   .014            NEG           NEG
             -     458910.           NEG          -   .016            NEG           NEG

403003020    +     458910.           NEG          +   .014            NEG           NEG
             -     458910.           NEG          -   .016            NEG           NEG
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Table 6-2-b. 1977 HC EVAPORATION UNCERTAINTIES (Continued)

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                                  HYDROCARBON EVAPORATION                          PAGE  9
TACR AND EMISSION UNCERTAINTIES PROJECTED TO 1977          RUN DATE= NOV 16,1977
 MODIFIED          TACRP                  EMISSIONS (MILLIONS OF TONS / YEAR)
   SCC          (SCC UNITS)        NOX                HC            CO            PART
403999000    +   10198000.         NEG        +     .047           NEG           NEG
             -   10198000.         NEG        -     .058           NEG           NEG

403999990    +   10198000.         NEG        +     .047           NEG           NEG
             -   10198000.         NEG        -     .058           NEG           NEG

406001000    +    8773700.         NEG        +     .093           NEG           NEG
             -    8773000.         NEG        -     .085           NEG           NEG

406001010    +    6004300.         NEG        +     .038           NEG           NEG
             -    6003800.         NEG        -     .061           NEG           NEG

406001011    +     107700.         NEG        +     .001           NEG           NEG
             -      71000.         NEG        -     .000           NEG           NEG
406001012    +    6003300.         NEG        +     .038           NEG           NEG
             -    6003300.         NEG        -     .061           NEG           NEG

406001020    +     524440.         NEG        +     .003           NEG           NEG
             -     524440.         NEG        -     .006           NEG           NEG

406001021    +      11544.         NEG        +     .000           NEG           NEG
             -      11544.         NEG        -     .000           NEG           NEG
406001022    +     524310.         NEG        +     .003           NEG           NEG
             -     524310.         NEG        -     .006           NEG           NEG

406001260    +    6353900.         NEG        +     .084           NEG           NEG
             -    6353400.         NEG        -     .057           NEG           NEG

406001261    +     107700.         NEG        +     .000           NEG           NEG
             -      77000.         NEG        -     .000           NEG           NEG
406001262    +    6353000.         NEG        +     .084           NEG           NEG
             -    6353000.         NEG        -     .057           NEG           NEG

406001270    +     527990.         NEG        +     .012           NEG           NEG
             -     527990.         NEG        -     .012           NEG           NEG

406001271    +      62241.         NEG        +     .000           NEG           NEG
             -      62241.         NEG        -     .000           NEG           NEG
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Table 6-2-b. 1977 HC EVAPORATION UNCERTAINTIES (Continued)

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                                  HYDROCARBON EVAPORATION                                PAGE 10
         TACR AND EMISSION UNCERTAINTIES PROJECTED TO 1977       RUN DATE= NOV 16,1977
          MODIFIED          TACRP                          EMISSIONS (MILLIONS OF TONS / YEAR)
            SCC          (SCC UNITS)              NOX                  HC            CO           PART

         406001272   +      524310.               NEG         +  .012           NEG           NEG
                     -      524310.               NEG         -  .012           NEG           NEG

         406002000   +    19465000.               NEG         +  .037           NEG           NEG
                     -    19465000.               NEG         -  .039           NEG           NEG

         406002010   +    12032000.               NEG         +  .019           NEG           NEG
                     -    12032000.               NEG         -  .013           NEG           NEG
         406002020   +     5597300.               NEG         +  .008           NEG           NEG
                     -     5597300.               NEG         -  .005           NEG           NEG
         406002260   +    12032000.               NEG         +  .014           NEG           NEG
                     -    12032000.               NEG         -  .012           NEG           NEG
         406002270   +     7615800.               NEG         +  .027           NEG           NEG
                     -     7615800.               NEG         -  .034           NEG           NEG
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Table 6-3-a. 1982 HC EVAPORATION EMISSIONS AND CHARGE RATES

```
                                    HYDROCARBON EVAPORATION                                PAGE  1
           ANNUAL CHARGE RATES AND EMISSIONS PROJECTED TO 1982       RUN DATE= NOV 16,1977
            MODIFIED          TACRP                EMISSIONS (MILLIONS OF TONS / YEAR)
              SCC          (SCC UNITS)            NOX          HC          CO          PART

           401001000             43230.           NEG         .001         NEG          NEG

           401001010             42800.           NEG         .001         NEG          NEG
           401001020               430.           NEG         .000         NEG          NEG

           401002000            114600.           NEG         .094         NEG          NEG

           401002010                 0.         0.000        0.000       0.000        0.000
           401002020               970.           NEG         .001         NEG          NEG
           401002030             15613.           NEG         .005         NEG          NEG
           401002050               970.           NEG         .001         NEG          NEG
           401002990             97450.           NEG         .088         NEG          NEG

           401999000            133700.           NEG         .011         NEG          NEG

           401999990            133700.           NEG         .011         NEG          NEG

           402001000            634340.           NEG         .118         NEG          NEG

           402001010            634340.           NEG         .118         NEG          NEG

           402001011            490000.           NEG         .110         NEG          NEG
           402001012            102000.           NEG         .006         NEG          NEG
           402001013              7680.           NEG         .000         NEG          NEG
           402001014              5930.           NEG         .000         NEG          NEG
           402001015             12420.           NEG         .001         NEG          NEG
           402001016              7970.           NEG         .000         NEG          NEG
           402001017              2860.           NEG         .000         NEG          NEG
           402001018              3860.           NEG         .000         NEG          NEG
           402001019              1623.           NEG         .000         NEG          NEG


           402002000           5944200.           NEG         .259         NEG          NEG

           402002010           5944200.           NEG         .259         NEG          NEG

           402002011             77300.           NEG         .036         NEG          NEG
           402002012             12400.           NEG         .002         NEG          NEG
```

Table 6-3-a. 1982 HC EVAPORATION EMISSIONS AND CHARGE RATES (Continued)

HYDROCARBON EVAPORATION PAGE 2

ANNUAL CHARGE RATES AND EMISSIONS PROJECTED TO 1982 RUN DATE= NOV 16,1977

MODIFIED SCC	TACRF (SCC UNITS)	EMISSIONS (MILLIONS OF TONS / YEAR) NOX	HC	CO	PART
402002013	84600.	NEG	.037	NEG	NEG
402002014	16400.	NEG	.015	NEG	NEG
402002015	5470000.	NEG	.115	NEG	NEG
402002016	43700.	NEG	.008	NEG	NEG
402002017	3540.	NEG	.001	NEG	NEG
402002018	45300.	NEG	.026	NEG	NEG
402002019	191000.	NEG	.019	NEG	NEG
402003000	427530.	NEG	.113	NEG	NEG
402003010	427530.	NEG	.113	NEG	NEG
402003011	420000.	NEG	.111	NEG	NEG
402003013	6600.	NEG	.002	NEG	NEG
402003014	396.	NEG	.000	NEG	NEG
402003017	429.	NEG	.000	NEG	NEG
402003019	108.	NEG	.000	NEG	NEG
402004000	102440.	NEG	.030	NEG	NEG
402004010	102440.	NEG	.030	NEG	NEG
402004011	47300.	NEG	.014	NEG	NEG
402004012	50400.	NEG	.015	NEG	NEG
402004015	4670.	NEG	.001	NEG	NEG
402004017	69.	NEG	.000	NEG	NEG
402005000	399150.	NEG	.092	NEG	NEG
402005010	399150.	NEG	.092	NEG	NEG
402005011	188500.	NEG	.043	NEG	NEG
402005012	201600.	NEG	.046	NEG	NEG
402005013	8500.	NEG	.002	NEG	NEG
402005016	234.	NEG	.000	NEG	NEG

Table 6-3-a. 1982 HC EVAPORATION EMISSIONS AND CHARGE RATES (Continued)

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                                   HYDROCARBON EVAPORATION                                      PAGE   3
ANNUAL CHARGE RATES AND EMISSIONS PROJECTED TO 1982      RUN DATE= NOV 16,1977
 MODIFIED          TACRF                    EMISSIONS (MILLIONS OF TONS / YEAR)
   SCC          (SCC UNITS)        NOX              HC               CO             PART
402005017              315.        NEG             .000             NEG             NEG

402006000          1378300.        NEG             .293             NEG             NEG

402006010          1378300.        NEG             .293             NEG             NEG

402006011          1348000.        NEG             .286             NEG             NEG
402006012            25200.        NEG             .005             NEG             NEG
402006014              379.        NEG             .000             NEG             NEG
402006016             4157.        NEG             .001             NEG             NEG
402006017              410.        NEG             .000             NEG             NEG
402006019              104.        NEG             .000             NEG             NEG

402007000          1666500.        NEG             .241             NEG             NEG

402007010          1666500.        NEG             .241             NEG             NEG

402007011           352000.        NEG             .229             NEG             NEG
402007012              284.        NEG             .000             NEG             NEG
402007013          1112000.        NEG             .011             NEG             NEG
402007014            11230.        NEG             .000             NEG             NEG
402007015           191000.        NEG             .001             NEG             NEG

402008000           231000.        NEG             .056             NEG             NEG

402008010           231000.        NEG             .056             NEG             NEG

402008011           105000.        NEG             .026             NEG             NEG
402008012           126000.        NEG             .031             NEG             NEG

402999000          1732200.        NEG             .129             NEG             .012

402999990          1732200.        NEG             .129             NEG             .012
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Table 6-3-a. 1982 HC EVAPORATION EMISSIONS AND CHARGE RATES (Continued)

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                              HYDROCARBON EVAPORATION                                PAGE  4
ANNUAL CHARGE RATES AND EMISSIONS PROJECTED TO 1982      RUN DATE= NOV 16,1977
 MODIFIED          TACRF                 EMISSIONS (MILLIONS OF TONS / YEAR)
   SCC          (SCC UNITS)         NOX             HC             CO            PART
403001000                            NEG            .082           NEG            NEG
403001010               0.         0.000          0.000          0.000          0.000
403001011               0.         0.000          0.000          0.000          0.000
403001020               0.         0.000          0.000          0.000          0.000
403001021               0.         0.000          0.000          0.000          0.000
403001030               0.         0.000          0.000          0.000          0.000
403001031               0.         0.000          0.000          0.000          0.000
403001040               0.         0.000          0.000          0.000          0.000
403001041               0.         0.000          0.000          0.000          0.000
403001050          124000.           NEG            .002           NEG            NEG
403001051          124000.           NEG            .002           NEG            NEG
403001060          500000.           NEG            .004           NEG            NEG
403001061          500000.           NEG            .004           NEG            NEG
403001070         6937600.           NEG            .050           NEG            NEG
403001071         6937600.           NEG            .050           NEG            NEG
403001500        52770000.           NEG            .027           NEG            NEG
403001501         1570000.           NEG            .002           NEG            NEG
403001510        20800000.           NEG            .010           NEG            NEG
403001511        20800000.           NEG            .010           NEG            NEG
```

Table 6-3-a. 1982 HC EVAPORATION EMISSIONS AND CHARGE RATES (Continued)

HYDROCARBON EVAPORATION PAGE 5

ANNUAL CHARGE RATES AND EMISSIONS PROJECTED TO 1982 RUN DATE= NOV 16,1977

MODIFIED SCC	TACRF (SCC UNITS)	EMISSIONS (MILLIONS OF TONS / YEAR) NOX	HC	CO	PART
403001520	30400000.	NEG	.014	NEG	NEG
403001521	30400000.	NEG	.014	NEG	NEG
403002000		NEG	.217	NEG	NEG
403002010	1920000.	NEG	.013	NEG	NEG
403002011	1920000.	NEG	.013	NEG	NEG
403002020	0.	0.000	0.000	0.000	0.000
403002021	0.	0.000	0.000	0.000	0.000
403002030	13040000.	NEG	.069	NEG	NEG
403002031	13040000.	NEG	.069	NEG	NEG
403002040	86000000.	NEG	.135	NEG	NEG
403002041	86000000.	NEG	.135	NEG	NEG
403002050	89700.	NEG	.000	NEG	NEG
403002051	89700.	NEG	.000	NEG	NEG
403002060	52000.	NEG	.000	NEG	NEG
403002061	52000.	NEG	.000	NEG	NEG
403002070	154000.	NEG	.000	NEG	NEG
403002071	154000.	NEG	.000	NEG	NEG
403003000	35860000.	NEG	.157	NEG	NEG

Table 6-3-a. 1982 HC EVAPORATION EMISSIONS AND CHARGE RATES (Continued)

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                              HYDROCARBON EVAPORATION                               PAGE  6
ANNUAL CHARGE RATES AND EMISSIONS PROJECTED TO 1982       RUN DATE= NOV 16,1977
 MODIFIED          TACRF                        EMISSIONS (MILLIONS OF TONS / YEAR)
   SCC          (SCC UNITS)          NOX              HC               CO              PART

403003020        35860000.           NEG             .157              NEG              NEG

403999000        15000000.           NEG             .069              NEG              NEG

403999930        15000000.           NEG             .069              NEG              NEG

406001000        83616000.           NEG             .057              NEG              NEG

406001010         4900000.           NEG             .030              NEG              NEG

406001011               0.         0.000            0.000            0.000            0.000
406001012         4900000.           NEG             .030              NEG              NEG

406001020         2011000.           NEG             .011              NEG              NEG

406001021           11000.           NEG             .000              NEG              NEG
406001022         2000000.           NEG             .011              NEG              NEG

406001260        61500000.           NEG             .013              NEG              NEG

406001261               0.         0.000            0.000            0.000            0.000
406001262        61500000.           NEG             .013              NEG              NEG

406001270        15205000.           NEG             .003              NEG              NEG

406001271          405000.           NEG             .000              NEG              NEG
406001272        14800000.           NEG             .003              NEG              NEG


406002000       112600000.           NEG             .239              NEG              NEG

406002010         3300000.           NEG             .001              NEG              NEG
406002020         6000000.           NEG             .002              NEG              NEG
406002260         3300000.           NEG             .000              NEG              NEG
406002270       100000000.           NEG             .235              NEG              NEG
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Table 6-3-b. 1982 HC EVAPORATION UNCERTAINTIES

```
                              HYDROCARBON EVAPORATION                                   PAGE  1
TACR AND EMISSION UNCERTAINTIES PROJECTED TO 1982           RUN DATE= NOV 16,1977
 MODIFIED          TACRF                      EMISSIONS (MILLIONS OF TONS / YEAR)
   SCC         (SCC UNITS)          NOX                 HC               CO              PART

401001000    +       35891.          NEG         +   .006              NEG               NEG
             -       22099.          NEG         -   .000              NEG               NEG

401001010    +       22095.          NEG         +   .004              NEG               NEG
             -       22095.          NEG         -   .000              NEG               NEG
401001020    +       28284.          NEG         +   .004              NEG               NEG
             -         430.          NEG         -   .000              NEG               NEG

401002000    +      110720.          NEG         +   .102              NEG               NEG
             -       97660.          NEG         -   .088              NEG               NEG

401002010    +           0.    + 0.000           + 0.000         + 0.000           + 0.000
             -           0.    - 0.000           - 0.000         - 0.000           - 0.000
401002020    +        2304.          NEG         +   .002              NEG               NEG
             -         570.          NEG         -   .001              NEG               NEG
401002030    +        6307.          NEG         +   .010              NEG               NEG
             -        6307.          NEG         -   .003              NEG               NEG
401002050    +        3667.          NEG         +   .003              NEG               NEG
             -         970.          NEG         -   .001              NEG               NEG
401002990    +      110450.          NEG         +   .101              NEG               NEG
             -       97450.          NEG         -   .088              NEG               NEG

401999000    +       34875.          NEG         +   .018              NEG               NEG
             -       34875.          NEG         -   .011              NEG               NEG

401999990    +       34875.          NEG         +   .018              NEG               NEG
             -       34875.          NEG         -   .011              NEG               NEG

402001000    +       84814.          NEG         +   .174              NEG               NEG
             -       84814.          NEG         -   .084              NEG               NEG

402001010    +       84814.          NEG         +   .174              NEG               NEG
             -       84814.          NEG         -   .084              NEG               NEG

402001011    +       67720.          NEG         +   .166              NEG               NEG
             -       67720.          NEG         -   .084              NEG               NEG
402001012    +       50515.          NEG         +   .052              NEG               NEG
             -       50515.          NEG         -   .003              NEG               NEG
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Table 6-3-b. 1982 HC EVAPORATION UNCERTAINTIES (Continued)

```
                        HYDROCARBON EVAPORATION                              PAGE  2
TACR AND EMISSION UNCERTAINTIES PROJECTED TO 1982        RUN DATE= NOV 16,1977
 MODIFIED          TACR                    EMISSIONS (MILLIONS OF TONS / YEAR)
   SCC          (SCC UNITS)        NOX            HC             CO              PART
402001013    +        2596.        NEG       +   .004           NEG              NEG
             -        2596.        NEG       -   .000           NEG              NEG
402001014    +        2926.        NEG       +   .003           NEG              NEG
             -        2926.        NEG       -   .000           NEG              NEG
402001015    +        5248.        NEG       +   .006           NEG              NEG
             -        5248.        NEG       -   .000           NEG              NEG
402001016    +        3016.        NEG       +   .004           NEG              NEG
             -        3016.        NEG       -   .000           NEG              NEG
402001017    +         368.        NEG       +   .001           NEG              NEG
             -         368.        NEG       -   .000           NEG              NEG
402001018    +        1108.        NEG       +   .002           NEG              NEG
             -        1108.        NEG       -   .000           NEG              NEG
402001019    +         327.        NEG       +   .001           NEG              NEG
             -         327.        NEG       -   .000           NEG              NEG

402002000    +     7563000.        NEG       +   .277           NEG              NEG
             -     5474900.        NEG       -   .131           NEG              NEG

402002010    +     7563000.        NEG       +   .277           NEG              NEG
             -     5474900.        NEG       -   .131           NEG              NEG

402002011    +      105380.        NEG       +   .049           NEG              NEG
             -       77300.        NEG       -   .036           NEG              NEG
402002012    +       16916.        NEG       +   .003           NEG              NEG
             -       12400.        NEG       -   .002           NEG              NEG
402002013    +      115480.        NEG       +   .050           NEG              NEG
             -       84600.        NEG       -   .037           NEG              NEG
402002014    +       22391.        NEG       +   .020           NEG              NEG
             -       16400.        NEG       -   .015           NEG              NEG
402002015    +     7496700.        NEG       +   .192           NEG              NEG
             -     5470000.        NEG       -   .115           NEG              NEG
402002016    +      950050.        NEG       +   .181           NEG              NEG
             -       43700.        NEG       -   .008           NEG              NEG
402002017    +        4836.        NEG       +   .001           NEG              NEG
             -        3540.        NEG       -   .001           NEG              NEG
402002018    +       61912.        NEG       +   .036           NEG              NEG
             -       45300.        NEG       -   .026           NEG              NEG
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Table 6-3-b. 1982 HC EVAPORATION UNCERTAINTIES (Continued)

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                           HYDROCARBON EVAPORATION                              PAGE   3
  TACR AND EMISSION UNCERTAINTIES PROJECTED TO 1982       RUN DATE= NOV 16,1977
  MODIFIED          TACRF              EMISSIONS (MILLIONS OF TONS / YEAR)
    SCC          (SCC UNITS)         NOX            HC            CO           PART
  402002019    +     260410.          NEG      +  .026           NEG           NEG
               -     191000.          NEG      -  .019           NEG           NEG

  402003000    +      56378.          NEG      +  .165           NEG           NEG
               -      56378.          NEG      -  .085           NEG           NEG

  402003010    +      56378.          NEG      +  .165           NEG           NEG
               -      56378.          NEG      -  .085           NEG           NEG

  402003011    +      56320.          NEG      +  .165           NEG           NEG
               -      56320.          NEG      -  .085           NEG           NEG
  402003013    +       2549.          NEG      +  .003           NEG           NEG
               -       2549.          NEG      -  .001           NEG           NEG
  402003014    +        195.          NEG      +  .000           NEG           NEG
               -        195.          NEG      -  .000           NEG           NEG
  402003017    +         55.          NEG      +  .000           NEG           NEG
               -         55.          NEG      -  .000           NEG           NEG
  402003019    +         89.          NEG      +  .000           NEG           NEG
               -         89.          NEG      -  .000           NEG           NEG

  402004000    +      26144.          NEG      +  .033           NEG           NEG
               -      26144.          NEG      -  .017           NEG           NEG

  402004010    +      26144.          NEG      +  .033           NEG           NEG
               -      26144.          NEG      -  .017           NEG           NEG

  402004011    +       6456.          NEG      +  .022           NEG           NEG
               -       6456.          NEG      -  .011           NEG           NEG
  402004012    +      25257.          NEG      +  .024           NEG           NEG
               -      25257.          NEG      -  .013           NEG           NEG
  402004019    +       1973.          NEG      +  .002           NEG           NEG
               -       1973.          NEG      -  .001           NEG           NEG
  402004017    +          8.          NEG      +  .000           NEG           NEG
               -          8.          NEG      -  .000           NEG           NEG
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Table 6-3-b. 1982 HC EVAPORATION UNCERTAINTIES (Continued)

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                                    HYDROCARBON EVAPORATION                             PAGE  4
TACR AND EMISSION UNCERTAINTIES PROJECTED TO 1982          RUN DATE= NOV 16,1977
  MODIFIED             TACRF                         EMISSIONS (MILLIONS OF TONS / YEAR)
    SCC            (SCC UNITS)             NOX              HC              CO             PART

402005000     +       104260.              NEG        +   .098             NEG             NEG
              -       104260.              NEG        -   .053             NEG             NEG

402005010     +       104260.              NEG        +   .098             NEG             NEG
              -       104260.              NEG        -   .053             NEG             NEG

402005011     +        25756.              NEG        +   .065             NEG             NEG
              -        25756.              NEG        -   .033             NEG             NEG
402005012     +       100980.              NEG        +   .073             NEG             NEG
              -       100980.              NEG        -   .041             NEG             NEG
402005013     +         3310.              NEG        +   .004             NEG             NEG
              -         3310.              NEG        -   .002             NEG             NEG
402005016     +           88.              NEG        +   .000             NEG             NEG
              -           88.              NEG        -   .000             NEG             NEG
402005017     +           40.              NEG        +   .000             NEG             NEG
              -           40.              NEG        -   .000             NEG             NEG

402006000     +       183970.              NEG        +   .453             NEG             NEG
              -       183970.              NEG        -   .218             NEG             NEG

402006010     +       183970.              NEG        +   .453             NEG             NEG
              -       183970.              NEG        -   .218             NEG             NEG

402006011     +       183520.              NEG        +   .453             NEG             NEG
              -       183520.              NEG        -   .218             NEG             NEG
402006012     +        12727.              NEG        +   .009             NEG             NEG
              -        12727.              NEG        -   .005             NEG             NEG
402006014     +          187.              NEG        +   .000             NEG             NEG
              -          187.              NEG        -   .000             NEG             NEG
402006016     +         1580.              NEG        +   .001             NEG             NEG
              -         1580.              NEG        -   .001             NEG             NEG
402006017     +           54.              NEG        +   .000             NEG             NEG
              -           54.              NEG        -   .000             NEG             NEG
402006019     +           21.              NEG        +   .000             NEG             NEG
              -           21.              NEG        -   .000             NEG             NEG
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Table 6-3-b. 1982 HC EVAPORATION UNCERTAINTIES (Continued)

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                             HYDROCARBON EVAPORATION                       PAGE  5
 TACR AND EMISSION UNCERTAINTIES PROJECTED TO 1982        RUN DATE= NOV 16,1977
 MODIFIED          TACRP                  EMISSIONS (MILLIONS OF TONS / YEAR)
   SCC          (SCC UNITS)        NOX             HC             CO          PART

 402007000   +     107080.         NEG      +   .125           NEG           NEG
             -     107080.         NEG      -   .186           NEG           NEG

 402007010   +     107080.         NEG      +   .125           NEG           NEG
             -     107080.         NEG      -   .186           NEG           NEG

 402007011   +      32159.         NEG      +   .125           NEG           NEG
             -      32159.         NEG      -   .186           NEG           NEG
 402007012   +         26.         NEG      +   .000           NEG           NEG
             -         26.         NEG      -   .000           NEG           NEG
 402007013   +     100520.         NEG      +   .001           NEG           NEG
             -     100520.         NEG      -   .007           NEG           NEG
 402007014   +       1005.         NEG      +   .001           NEG           NEG
             -       1005.         NEG      -   .000           NEG           NEG
 402007015   +      18084.         NEG      +   .000           NEG           NEG
             -      18084.         NEG      -   .001           NEG           NEG

 402008000   +      65220.         NEG      +   .062           NEG           NEG
             -      65220.         NEG      -   .034           NEG           NEG

 402008010   +      65220.         NEG      +   .062           NEG           NEG
             -      65220.         NEG      -   .034           NEG           NEG

 402008011   +      14272.         NEG      +   .038           NEG           NEG
             -      14272.         NEG      -   .020           NEG           NEG
 402008012   +      63639.         NEG      +   .049           NEG           NEG
             -      63639.         NEG      -   .028           NEG           NEG

 402999000   +     470300.         NEG      +   .112           NEG       +  .003
             -     470300.         NEG      -   .112           NEG       -  .003

 402999990   +     470300.         NEG      +   .112           NEG       +  .003
             -     470300.         NEG      -   .112           NEG       -  .003

 403001000                         NEG      +   .017           NEG           NEG
                                   NEG      -   .035           NEG           NEG
```

Table 6-3-b. 1982 HC EVAPORATION UNCERTAINTIES (Continued)

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                              HYDROCARBON EVAPORATION                               PAGE   6
TACR AND EMISSION UNCERTAINTIES PROJECTED TO 1982          RUN DATE= NOV 16,1977
 MODIFIED          TACR                    EMISSIONS (MILLIONS OF TONS / YEAR)
   SCC          (SCC UNITS)          NOX            HC               CO              PART
403001010    +            0.     + 0.000     + 0.000      + 0.000       + 0.000
             -            0.     - 0.000     - 0.000      - 0.000       - 0.000

403001011    +            0.     + 0.000     + 0.000      + 0.000       + 0.000
             -            0.     - 0.000     - 0.000      - 0.000       - 0.000

403001020    +            0.     + 0.000     + 0.000      + 0.000       + 0.000
             -            0.     - 0.000     - 0.000      - 0.000       - 0.000

403001021    +            0.     + 0.000     + 0.000      + 0.000       + 0.000
             -            0.     - 0.000     - 0.000      - 0.000       - 0.000

403001030    +            0.     + 0.000     + 0.000      + 0.000       + 0.000
             -            0.     - 0.000     - 0.000      - 0.000       - 0.000

403001031    +            0.     + 0.000     + 0.000      + 0.000       + 0.000
             -            0.     - 0.000     - 0.000      - 0.000       - 0.000

403001040    +            0.     + 0.000     + 0.000      + 0.000       + 0.000
             -            0.     - 0.000     - 0.000      - 0.000       - 0.000

403001041    +            0.     + 0.000     + 0.000      + 0.000       + 0.000
             -            0.     - 0.000     - 0.000      - 0.000       - 0.000

403001050    +      128060.          NEG     +  .002          NEG           NEG
             -      124000.          NEG     -  .002          NEG           NEG

403001051    +      128060.          NEG     +  .002          NEG           NEG
             -      124000.          NEG     -  .002          NEG           NEG

403001060    +      500000.          NEG     +  .004          NEG           NEG
             -      500000.          NEG     -  .004          NEG           NEG

403001061    +      500000.          NEG     +  .004          NEG           NEG
             -      500000.          NEG     -  .004          NEG           NEG

403001070    +      896440.          NEG     +  .008          NEG           NEG
             -      896440.          NEG     -  .032          NEG           NEG
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Table 6-3-b. 1982 HC EVAPORATION UNCERTAINTIES (Continued)

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                          HYDROCARBON EVAPORATION                        PAGE  7
TACR AND EMISSION UNCERTAINTIES PROJECTED TO 1982       RUN DATE= NOV 16,1977
 MODIFIED          TACRF               EMISSIONS (MILLIONS OF TONS / YEAR)
   SCC          (SCC UNITS)        NOX            HC            CO         PART

403001071   +       896440.          NEG      +  .008           NEG          NEG
            -       896440.          NEG      -  .032           NEG          NEG

403001500   +     28339000.          NEG      +  .014           NEG          NEG
            -     28328000.          NEG      -  .014           NEG          NEG

403001501   +      1760000.          NEG      +  .002           NEG          NEG
            -      1570000.          NEG      -  .002           NEG          NEG

403001510   +     20000000.          NEG      +  .010           NEG          NEG
            -     20000000.          NEG      -  .010           NEG          NEG

403001511   +     20000000.          NEG      +  .010           NEG          NEG
            -     20000000.          NEG      -  .010           NEG          NEG

403001520   +     20000000.          NEG      +  .010           NEG          NEG
            -     20000000.          NEG      -  .010           NEG          NEG

403001521   +     20000000.          NEG      +  .010           NEG          NEG
            -     20000000.          NEG      -  .010           NEG          NEG


403002000                            NEG      +  .149           NEG          NEG
                                     NEG      -  .140           NEG          NEG

403002010   +      7982900.          NEG      +  .053           NEG          NEG
            -      1920000.          NEG      -  .013           NEG          NEG

403002011   +      7982900.          NEG      +  .053           NEG          NEG
            -      1920000.          NEG      -  .013           NEG          NEG

403002020   +            0.      + 0.000      + 0.000       + 0.000      + 0.000
            -            0.      - 0.000      - 0.000       - 0.000      - 0.000

403002021   +            0.      + 0.000      + 0.000       + 0.000      + 0.000
            -            0.      - 0.000      - 0.000       - 0.000      - 0.000
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Table 6-3-b. 1982 HC EVAPORATION UNCERTAINTIES (Continued)

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                          HYDROCARBON EVAPORATION                          PAGE  8
TACR AND EMISSION UNCERTAINTIES PROJECTED TO 1982         RUN DATE= NOV 16,1977
 MODIFIED         TACRP                      EMISSIONS (MILLIONS OF TONS / YEAR)
   SCC        (SCC UNITS)           NOX              HC          CO          PAFT

403002030   +     8062300.          NEG        +   .043         NEG          NEG
            -     8062300.          NEG        -   .058         NEG          NEG

403002031   +     8062300.          NEG        +   .043         NEG          NEG
            -     8062300.          NEG        -   .058         NEG          NEG

403002040   +    20100000.          NEG        +   .133         NEG          NEG
            -    20100000.          NEG        -   .126         NEG          NEG

403002041   +    20100000.          NEG        +   .133         NEG          NEG
            -    20100000.          NEG        -   .126         NEG          NEG

403002050   +       99408.          NEG        +   .000         NEG          NEG
            -       89700.          NEG        -   .000         NEG          NEG

403002051   +       99408.          NEG        +   .000         NEG          NEG
            -       89700.          NEG        -   .000         NEG          NEG

403002060   +       45276.          NEG        +   .000         NEG          NEG
            -       45276.          NEG        -   .000         NEG          NEG

403002061   +       45276.          NEG        +   .000         NEG          NEG
            -       45276.          NEG        -   .000         NEG          NEG

403002070   +      135830.          NEG        +   .000         NEG          NEG
            -      135830.          NEG        -   .000         NEG          NEG

403002071   +      135830.          NEG        +   .000         NEG          NEG
            -      135830.          NEG        -   .000         NEG          NEG


403003000   +      904490.          NEG        +   .027         NEG          NEG
            -      904490.          NEG        -   .101         NEG          NEG

403003020   +      904490.          NEG        +   .027         NEG          NEG
            -      904490.          NEG        -   .101         NEG          NEG
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Table 6-3-b. 1982 HC EVAPORATION UNCERTAINTIES (Continued)

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                            HYDROCARBON EVAPORATION                       PAGE  9
TACR AND EMISSION UNCERTAINTIES PROJECTED TO 1982        RUN DATE= NOV 16,1977
 MODIFIED          TACRF                 EMISSIONS (MILLIONS OF TONS / YEAR)
   SCC          (SCC UNITS)          NOX             HC              CO           PART

403999000   +   20100000.            NEG       +  .093             NEG            NEG
            -   15000000.            NEG       -  .069             NEG            NEG

403999990   +   20100000.            NEG       +  .093             NEG            NEG
            -   15000000.            NEG       -  .069             NEG            NEG

406001000   +   17757000.            NEG       +  .170             NEG            NEG
            -   13908000.            NEG       -  .035             NEG            NEG

406001010   +   12078000.            NEG       +  .075             NEG            NEG
            -    4900000.            NEG       -  .030             NEG            NEG

406001011   +          0.        + 0.000       + 0.000         + 0.000        + 0.000
            -          0.        - 0.000       - 0.000         - 0.000        - 0.000
406001012   +   12078000.            NEG       +  .075             NEG            NEG
            -    4900000.            NEG       -  .030             NEG            NEG

406001020   +     911180.            NEG       +  .005             NEG            NEG
            -     910890.            NEG       -  .010             NEG            NEG

406001021   +      25355.            NEG       +  .000             NEG            NEG
            -      11000.            NEG       -  .000             NEG            NEG
406001022   +     910820.            NEG       +  .005             NEG            NEG
            -     910820.            NEG       -  .010             NEG            NEG

406001260   +   12952000.            NEG       +  .150             NEG            NEG
            -   12952000.            NEG       -  .013             NEG            NEG

406001261   +          0.        + 0.000       + 0.000         + 0.000        + 0.000
            -          0.        - 0.000       - 0.000         - 0.000        - 0.000
406001262   +   12952000.            NEG       +  .150             NEG            NEG
            -   12952000.            NEG       -  .013             NEG            NEG

406001270   +     916270.            NEG       +  .028             NEG            NEG
            -     916270.            NEG       -  .003             NEG            NEG

406001271   +      99744.            NEG       +  .001             NEG            NEG
            -      99744.            NEG       -  .000             NEG            NEG
```

Table 6-3-b. 1982 HC EVAPORATION UNCERTAINTIES (Continued)

```
                                  HYDROCARBON EVAPORATION                                   PAGE 10
       TACR AND EMISSION UNCERTAINTIES PROJECTED TO 1982         RUN DATE= NOV 16,1977
        MODIFIED          TACRF                     EMISSIONS (MILLIONS OF TONS / YEAR)
          SCC         (SCC UNITS)           NOX                 HC             CO              PART

       406001272    +      910820.          NEG        +   .028           NEG              NEG
                    -      910820.          NEG        -   .003           NEG              NEG

       406002000    +    41372000.          NEG        +   .114           NEG              NEG
                    -    13068000.          NEG        -   .123           NEG              NEG

       406002010    +    27014000.          NEG        +   .012           NEG              NEG
                    -     3300000.          NEG        -   .001           NEG              NEG
       406002020    +    11795000.          NEG        +   .008           NEG              NEG
                    -     6000000.          NEG        -   .002           NEG              NEG
       406002260    +    27014000.          NEG        +   .005           NEG              NEG
                    -     3300000.          NEG        -   .000           NEG              NEG
       406002270    +    10630000.          NEG        +   .113           NEG              NEG
                    -    10630000.          NEG        -   .123           NEG              NEG
```

marginally profitable to produce; consequently, older plants are not being replaced as they enter obsolescence. On the other hand, trichloroethylene is very photochemically reactive and has been banned from uncontrolled use in many areas. For these reasons, perchloroethylene is expected to emerge as the prominent solvent in the next decade.

6.3.2 Surface Coating

Hydrocarbon emissions from paint and other surface coatings occur during application and result primarily from the evaporation of the thinning agent (solvent). A second source of HC emissions is the film formers called resins. The thinner is in the coating to allow application in the liquid state. Although solid (powder) surface coating has been applied and baked with some success in a few limited applications, it is not expected to serve as a significant substitute for liquid coatings in the near future.

The total quantity of surface coatings used nationwide in 1974 was essentially divided equally between industrial applications and trade or retail sales. Since the trade-sales surface coatings are almost exclusively area source emissions, they were not included in this study.

For a better insight into the source of the surface coating emissions, the SCC numbers were subdivided into types of products such as motor vehicles, appliances, and machinery. In 1972, the sheet, strip, and coil industry and the paper industry each represented the source of about a billion pounds of HC discharged to the atmosphere. Motor vehicles and fabric treatment plants each contributed about 0.4-billion pounds. All other activities combined contributed less than 10 percent of the emissions from surface coatings. The emissions from industrial surface coatings come from approximately 10,000 point sources which are widespread geographically.

At the start of this study, no activity had been assigned by the NEDS to the SCC numbers 402002xx nor 402007xx. For this study, these numbers were respectively assigned to paper products and fabric treatment. In the meantime (December 1975), the SCC category number 402007xx was assigned by EPA to adhesives. This represents the only inconsistency between the NEDS numbering system and the modified SCC system described in Table 6-1.

A more detailed description of the industrial surface coating industry is found in Ref. 6-3.

6.3.3 Petroleum Product Storage

Although many types of storage facilities have been developed to retard the loss of petroleum products to the atmosphere, three types store significant quantities of product and were consequently considered in this study: (1) fixed-roof tank, (2) floating-roof tank, and (3) variable vapor-space tank.

According to Ref. 6-1, five products are significant contributors (≥500 tons per year) to atmospheric emissions: (1) gasoline, (2) crude oil, (3) jet fuel (JP-4), (4) kerosene, and (5) distillate fuel.

Although all five fluids contributed to emissions from fixed-roof and floating-roof tanks, only gasoline was found to be a significant emitter of vapor from the variable vapor-space tank. Reference 6-4 describes the causes of and influencing factors on evaporation from petroleum product storage tanks. Although initial motives for developing the floating-roof and variable vapor-space tanks were essentially economic through conservation of the products, pollution alleviation characteristics are inherent. Recent improvements have been directed toward the pollution control aspects of these facilities.

The American Petroleum Institute (API) coordinated efforts as early as 1952 to correlate evaporation losses to tank and fluid variables. Empirically derived equations which relate the evaporative losses to the independent variables for the fixed-roof, floating-roof, and variable vapor-space tanks are respectively described in Refs. 6-5 through 6-7.

For purposes of emissions data, storage, and handling, as in Refs. 6-1 and 6-2, emissions from the storage tanks are calculated from an equation which is a function only of two variables, the emission factor and the charge rate as defined in Table 6-1. Reference 6-8 lists the EPA-recommended emission factors. To capitalize on the API analysis, it was necessary to convert the API empirically derived equations into the two-variable equation. This was accomplished by rearranging the API equations as necessary to include the Table 6-1 charge rate as one of the variables. For example, the API breathing loss equation is a function of tank diameter to the 1.73 power and the average vapor space depth to the 0.51 power, which in turn are related to tank capacity. Through proper substitution, the tank capacity (which is the Table 6-1 charge rate) can appear in the API equation. The product of all other terms in the API equation corresponds to the emission factors. If nominal values are assigned to these terms, an emission factor can be calculated which corresponds to the nominal conditions. Section 6.5 describes the development of the modified API equation for the subject evaporation losses.

6.3.4 Marketing and Transportation of Petroleum Products

6.3.4.1 Point Source Emissions

Significant loss of HC vapors to the atmosphere is encountered in two of the operations involved in marketing and transportation of petroleum products. These two operations are (1) loading railraod tank cars and tank trucks and (2) loading and unloading of marine vessels.

6.3.4.2 Area Source Emissions

Although large quantities of HC emissions are attributed to unloading tank trucks and filling motor vehicles at retail service stations, none dispense sufficient quantities to qualify as a point source. To qualify as a point source emission (≥100 tons/year) with 1975 emission factors (~ 10 lb/1000 gal transferred), filling stations would have to pump approximately 20-million gal/year. Although NEDS lists 45 stations under the broad heading of vapor displacement sources (4-06-004-01), the composite total annual charge rate from these sources is only 4.593-million gal. Also, a personal communication with a representative of Standard Oil Company, El Segundo, California, indicated that the rates of their higher filling stations are 160,000-gal/month (~ 2-million gal/year). It was concluded that no filling stations qualify as point sources. Table 6-4 lists the HC emission losses at service stations.

6.4 EMISSIONS ANALYSIS

This section describes certain of the hypotheses, assumptions, and observations that were made in the course of establishing the data base on which the charge rate and emission rate calculations are based.

6.4.1 Cleaning Solvents

The change in charge rate (tons of clothing per year) for the dry cleaning processes reflects two things:

a. The phasing out of petroleum solvent is assumed to be completed in a 10-year period starting in 1972. The synthetic solvent is expected to fill this void.

b. The expected annual population growth rate is 0.9 percent from 1972 to 1980.

The degreasing sector of cleaning solvent usage is also under scrutiny, and the distribution of usage rates among the four major solvents is expected to be realigned. The Stoddard solvent is expected to disappear from the market because petroleum companies are not replacing antiquated facilities for reasons of poor profit forecasts. Also, trichloroethane and trichloroethylene uses are expected to be restricted to operations where emissions are highly controlled. These solvents are highly photochemically reactive. Perchloroethylene is expected to make up the deficit created by the declining use of these two solvents.

The general industrial usage rate of solvents is also expected to increase by 3 percent per year, which is the typical growth rate of manufactured goods over the last 10 years. This growth is also factored into the perchloroethylene and miscellaneous solvent usage rate change.

Table 6-4. EVAPORATION FROM SERVICE STATIONS: GASOLINE TRANSFERRED CHARGE RATES AND EMISSIONS

MSCC	Gasoline Pumped, 1000 gal/yr		HC Emissions, million tons/yr		Activity
	1976	1981	1976	1981	
A406004011	5.69E7	5.69E7	0.138	0.023	Vapor displacement during fill
A406004012	3.56E7	3.56E7	0.094	0.016	Vapor displacement during fill
A406004013	9.14E6	9.14E6	0.040	0.040	Vapor displacement during fill
Total Sales	1.016E8	1.016E8	0.272	0.079	
A406004020	1.016E8	1.016E8	0.006	0.005	Spillage
Total			0.278	0.084	
A406003010	5.772E7	-0-	0.332	-0-	Filling underground storage
A406003020	3.902E6	1.040E7	0.014	0.038	Filling underground storage
A406003030	1.532E7	4.080E7	0.006	0.016	Filling underground storage
A406003040	2.401E7	5.040E7	-0-	-0-	Filling underground storage
Total Storage	1.016E8	1.016E8	0.352	0.054	
Total Service Station Activity			0.630	0.138	

6.4.2 Surface Coating

Except for motor vehicles, the 1972 data in Ref. 6-3 were used to establish the baseline values for charge rates (quantity of surface coating used) and the emission factors (percent of surface coating comprised by solvent) from which projections were made.

Although the data published in Ref. 6-9 are based on a sample survey and the actual usage numbers may be somewhat different from the published numbers, the percentage changes per year are considered accurate. For this reason, the Ref. 6-9 data were used as a basis for establishing the slope and slope uncertainty of the time-usage curve of the respective industrial surface coating applications.

Automobile, truck, and bus production data extracted from Refs. 6-10 and 6-11 were the basis for estimating vehicle production and paint usage rates.

Reference 6-12 listed 26 lb of paint and other surface coating as being used on the Plymouth Fury, which is considered an average passenger car. Bus and truck usages were estimated on the basis of their relative surface area to the passenger car area.

6.4.3 Petroleum Product Storage

The API equations are intended for calculating the evaporative emissions under a particular set of storage conditions. At this writing, an inventory of facilities grouped according to the various influencing parameters is not available. Hence, an emission factor was determined for each tank type and stored fluid on the basis of a set of conditions that are considered typical. For example, for gasoline stored in a fixed-roof tank, the breathing losses might be calculated by means of the following typical parameters:

Storage Temperature	63°F
Average Daily Temperature Excursion	15°F
True Vapor Pressure	5.8 psia
Density	6.2 lb/gal

Paint Factor	1.14
Tank Depth	48 ft
Tank Diameter	110 ft
Factor for Liquid Stored (Gasoline)	0.024

Although the above variables may be typical (average) for fixed-roof gasoline storage, the real nationwide emissions as calculated by summing the emissions from individual tanks using the API equations do not equal the emissions calculated from the EPA equations using an emission factor based on the above typical values. The exact error is dependent on the distribution and range of variation of the independent variables. This error also results from the nonlinear effects of certain independent variables.

Section 6.6 shows the error due to distribution of tank geometry in calculated emissions using the EPA equation and a specific distribution and range of variation of tank diameter and height for fixed-roof gasoline tanks. Although the distribution of the independent variables used in Section 6.6 is highly unusual, it is intended to show the maximum error for the one emission factor concept. In addition to this error, an error in emission calculated for a group of tanks results of the true average of a particular independent variable was different from the assumed value. Section 6.7 shows the effect of using an emission factor based on one set of conditions when another set prevails.

The uncertainty of the emission factor was established either as (1) 10 percent of the nominal level, or (2) the difference between the emission factor listed in Ref. 6-8 and the one calculated from typical variables using the equation developed in Section 6.5, whichever was greater. This represents an overall uncertainty, i.e., the composite effect of the uncertainty of the individual parameters is reflected in the emission factor uncertainty.

According to Ref. 6-13, the stocks of gasoline at the end of the year have been essentially the same for the past six years. Since the total storage capacity is a linear function of the average stock on hand (which is based on politically decided reserves), no change in total gasoline capacity is forecast, at least through 1980. Based on a private communication with Standard Oil of California personnel, it appears that the use of fixed-roof storage tanks for gasoline may disappear as early as 1980. It is estimated that approximately 20 percent of the storage loss will be made up by floating-roof tanks and the remainder by variable vapor-space systems. The distribution of gasoline storage capacity among the three types of tanks is necessary for breathing loss calculations.

Although the number of motor vehicles (as well as total vehicle miles traveled) is expected to increase well beyond 1980, the estimated gasoline demand for highway usage is expected to remain near 100-billion gal/year. The primary reason that consumption is likely to remain constant while the car population increases is the improved mileage of current and future autos. Therefore, in estimating the working vapor losses of gasoline, the total throughput is considered constant with 80 percent of fixed-roof throughput being replaced by floating-roof facilities and 20 percent by variable vapor-space systems.

The floating-roof tanks will take over the majority of the gasoline throughput formerly handled by the fixed-roof tanks because of their superior control of HC emissions during filling and while empty. The variable vapor-space system breathing losses during static storage are near zero and consequently will represent about 60 percent of the gasoline storage capacity by 1981.

6.4.4 Marketing and Transportation of Petroleum Products

Point source emissions in 1977 from marketing and transportation of petroleum products are principally from operations involving the splash loading of gasoline on tank trucks (0.12-million tons/year of HC and the unloading of crude from marine vessels (0.11-million tons/year of HC). Emissions from these sources are expected to be reduced to 0.03-million tons/year and increased to 0.2-million tons/year of HC vapors, respectively, in 1982. Both activities will have lower emission factors in 1982, primarily through the implementation of vapor control techniques, such as use of the submerged fill pipe. For example, for gasoline loading, the emission factor with a submerged fill pipe is about one third as great as with the splash fill. Although the vapor recovery system (either balance or vacuum assist) potentially can capture and retain between 90 and 100 percent of the vapors formed, few systems have been installed where the transfer is potentially from any one of several sources or to one of several receptacle tanks. This is in contrast to the system used in filling underground storage tanks at filling stations which cycles the vapors from the tank to the truck through the annular coax line, which is integrated with the fill line.

Since no distinction was made between the petroleum movement by tank trucks and railroad tank cars in the NEDS SCC system, The Aerospace Corporation MSCC was adapted with a "1" in the 9th digit for railroad tank cars and a "2" for tank trucks (motorized vehicles for highway usage).

According to Ref. 6-14, the movement of gasoline by rail is on the decline. Should the trend continue, that form of gasoline movement may disappear by the early 1980s. That trend, coupled with some implementation of emission control measures, indicates that emissions from the loading of gasoline onto railroad cars (both splash and submerged) may be near zero by 1982.

Although the movement of crude by rail has experienced many ups and downs in the last decade, the trend seems to reflect a constant usage rate. The splash loading technique is expected to be replaced by submerged loading of crude.

The total petroleum loading movement (both gasoline and crude) was apportioned between splash and submerged according to the split that was reflected in the NEDS data.

6.5 EMISSION FACTORS DERIVED FROM API ANALYSIS

In order that emission factors might be derived (or confirmed) for evaporative losses from petroleum storage tanks, empirically derived equations from the API analysis described in Refs. 6-5 through 6-7 are utilized. Values for the terms can be found in the respective references when emissions are to be determined for specific conditions.

6.5.1 Fixed-Roof Breathing Losses

The API equation for fixed-roof breathing losses is taken from Ref. 6-5:

$$Ly = C\left(\frac{P}{14.7-P}\right)^{0.68} D^{1.73} H^{0.51} \Delta T^{0.50} F_p \qquad (6\text{-}1)$$

where:

L_y = breathing loss (bbl/year)

C = adjustment factor for small tanks ($C = 100$ for $D \geq 30$ ft)

P = true vapor pressure based on average bulk temperature (psia)

D = tank diameter (ft)

H = average vapor space depth (ft)

ΔT = average daily ambient temperature excursion (maximum minus minimum)(°F)

F_p = paint factor (no dimensions): 1.00 for all-white tank with paint in good condition.

The following definitions apply:

$$V = \frac{\pi D^2}{4} d \qquad \text{or} \qquad D^2 = \frac{4V}{\pi d} \qquad (6\text{-}2)$$

$$D^{1.73} = \frac{D^2}{D^{0.27}}$$

$$D^{1.73} = \frac{4V}{\pi d D^{0.27}} \qquad (6\text{-}2a)$$

$$Q = 7.48 \times 10^{-3} V \tag{6-3}$$

$$E = L_y \times 42\ (\text{gal/bbl}) \times \rho \tag{6-4}$$

and the following assumption was made:

$$H_{\text{average}} = 0.5\ d \tag{6-5}$$

where

V = tank volume capacity (cu ft)
d = equivalent height of cylindrical volume (ft)
Q = tank volume capacity (1000 gal)(SCC units)
E = evaporative loss by breathing (lb/year)
ρ = liquid density at average bulk temperature (lb/gal)

Substituting definitions of Eqs. (6-2a), (6-3), and (6-4) and the assumption, Eq. (6-5), into the API equation, Eq. (6-1), for breathing losses yields:

$$E = \left[5020.33\ \rho C \left(\frac{P}{14.7 - P} \right)^{0.68} \frac{\sqrt{\Delta_T}\ F_p}{d^{0.49} D^{0.27}} \right] Q \tag{6-6}$$

where the product of terms in the brackets represents the emission factor in (lb/yr)/1000-gal capacity:

$$E = EF \times Q \tag{6-7}$$

which is the EPA equation form.

6.5.2 Fixed-Roof Working Losses

The API equation for fixed-roof working losses is also taken from Ref. 6-5:

$$F = CPVK_t \tag{6-8}$$

where

C = factor dependent on liquid stored
P = true vapor pressure based on average bulk temperature (psia)
V = annual throughput (bbl/year)
K_t = turnover factor (dimensionless)
F = working loss (bbl/year)

The following definitions apply:

$$V = Q \times \left(\frac{1000}{42}\right) \tag{6-9}$$

$$E = F \times 42 \times \rho \tag{6-10}$$

where

E = working loss (lb/year)
Q = annual throughput (1000 gal/year)
ρ = density of liquid at average bulk temperature (lb/gal)

Substituting Eqs. (6-9) and (6-10) into the API equation, Eq. (6-8), for working losses yields:

$$E = \left[1000\ C\rho P\ K_t\right]Q \tag{6-11}$$

where the product of terms in the brackets represents the emission factor in (lb/year)/1000-gal throughput.

6.5.3 Standing Losses from Floating-Roof Tanks

The API equation for standing losses from floating-roof tanks is taken from Ref. 6-6:

$$L_y = K_t K_s K_c K_p D^{1.5} \left(\frac{wP}{14.7 - P}\right)^{0.7} \qquad (6\text{-}12)$$

where

L_y = standing loss (bbl/year)
K_t = tank-type factor
K_s = seal factor
K_c = fluid factor
K_p = paint factor
D = tank diameter (ft)
(for $D > 150$, replace $D^{1.5}$ with $12.25D$)
w = average wind velocity (mph)

The following definitions apply:

$$D^{1.5} = \frac{4V}{\pi d \sqrt{D}} \qquad (6\text{-}13)$$

$$V = \frac{1000}{7.48} Q \qquad (6\text{-}14)$$

$$E = 42 \times \rho \times L_y \qquad (6\text{-}15)$$

where

V = volumetric capacity (cu ft)
Q = volumetric capacity (1000/gal)
d = equivalent cylindrical depth of the tank (ft)
ρ = liquid density (lb/gal) at average bulk temperature

Substituting Eqs. (6-13) through (6-15) into the API equation, Eq. (6-12), yields:

$$E = \left[\frac{7149\ \rho K_t K_s K_c K_p}{\sqrt{D}\ d} \left(\frac{wP}{14.7 - P} \right)^{0.7} \right] Q \qquad (6\text{-}16)$$

where the product of terms in the brackets represents the emission factor in (lb/year)/1000-gal capacity.

6.5.4 Working Losses from Floating-Roof Tanks

API developed a clingage factor, c, which reflects the barrels of liquid per 1000 ft which cling to the wall and are exposed to the atmosphere to evaporate during a withdrawal process, when the floating roof slides down with the liquid surface.

This results in the following API emissions equation (Ref. 6-6):

$$E = (22.46\ c\rho)Q \qquad (6\text{-}17)$$

where

c = clingage factor (bbl/1000 sq ft of wetted wall surface)
ρ = liquid density at average bulk temperature (lb/gal)
Q = petroleum product withdrawn (1000 gal/year)
E = emissions (lb/year)

6.5.5 Working Losses from Variable Vapor-Space Tank Systems

Except for unplanned leakage, no vapor is lost to the atmosphere from variable vapor-space systems until vapor volume tends to exceed the expansion capacity of the system; then it behaves essentially like a fixed-roof storage facility. This is the basis for the equation which determines the emission from the variable vapor-space system. The only difference from the fixed-roof working losses is that the throughput term Q of Eq. (6-11) becomes only that throughput which exceeds the available expansion remaining at the start of the fill operation.

Let Q in Eq. (6-11) be replaced by ΔQ where ΔQ is defined as the volume of liquid transferred after the vapor expansion system reached its limit. Another way to express ΔQ is the difference between the total liquid transferred and the expansion capability remaining at the start of the operation.

To further simplify the referenced equation, three assumptions are made that represent the average system and its operation:

a. Available expansion volume at the start of the operation is one-fourth the total expansion capability of the system.

b. Each transfer involves a complete turnover; i.e., the quantity transferred equals the capacity of the tank.

c. Expansion capacity equals three-fourths of total liquid capacity of the tank.

The following equation represents the emissions expelled during filling operations of the variable vapor space:

$$E = (810\ C\rho P)Q \qquad (6\text{-}18)$$

where

E = emissions (lb/yr)

C = factor dependent on liquid stored

ρ = density of liquid at average bulk temperature (lb/gal)

P = true vapor pressure based on average bulk temperature (psia)

Q = annual throughput (1000 gal/yr)

Reference 6-7 describes the variable vapor space system in greater detail.

Since the expansion capacity is seldom exceeded while the system is in a standby mode, the breathing loss is considered negligible.

6.6 COMPARISON OF API AND EPA EMISSION EQUATIONS

Unless an extensive expansion of the SCC system is effected, one emission factor (EF) value must be used for a broad range of variables. Use of the EPA equation, which is a simplified version of the API equation, introduces an error in the calculated emission. The limits of this error can be determined from a comparison of the breathing losses of a group of fixed-roof gasoline storage tanks calculated from the API and EPA equations, respectively. The population of tanks is made up of two subgroups, one with diameters that are 0.90 and the other 1.1 of the average diameter. Both subgroups have an equal number n in the set. Although this is a highly unusual distribution, it was selected for the comparison to show the upper limit of the error. All other variables are the same for the entire group. A similar comparison is made for varying depth.

From Section 6.5.1, the API equations yield the following emissions in terms of D (average tank diameter) and Q, the capacity of the tank with an average diameter D:

$$E = n \times 42\,\rho C\left(\frac{P}{14.7 - P}\right)^{0.68} H^{0.51}\ \sqrt{\Delta T}\ F_p \times \left[(0.9D)^{1.73} + (1.1D)^{1.73}\right] \tag{6-19}$$

Factoring $D^{1.73}$ and substituting the following

$$\begin{aligned} Q &= 7.481 \times 10^{-3}\, V \\ &= 7.481 \times 10^{-3}\left(\frac{\pi D^2}{4} \times d\right) \end{aligned} \tag{6-20}$$

or rearranging

$$D^{1.73} = \frac{4Q}{7.481 \times 10^{-3}\, dD^{0.27}\pi} \tag{6-21}$$

and letting

$$H = 0.5\ d \qquad (6\text{-}22)$$

and

$$EF = \frac{5020.3\ F_p \rho c}{d^{0.49}\ D^{0.27}} \left(\frac{P}{14.7 - P}\right)^{0.68} \sqrt{\Delta T} \qquad (6\text{-}23)$$

then, it is found that

$$\begin{aligned} E &= n \times EF \times Q \left(0.9^{1.73} + 1.1^{1.73}\right) \\ E &= 2.01 \times n \times EF \end{aligned} \qquad (6\text{-}24)$$

The EPA emission equation is simply the product of an emission factor EF and the tank capacity. Although the emissions can be calculated for each tank using its particular capacity, no provisions exist for adjusting the emission factor from tank to tank even though it is a function of tank diameter. Instead the emissions from a group of tanks are calculated from some representative emission factor based on a typical set of independent variables, such as an average diameter of the group.

The EPA emission equation yields the following emissions for a group of 2n tanks, using an emission factor EF based on the average diameter D:

$$\begin{aligned} E &= n \times EF \times \left[\frac{\pi(0.9D^2)\ d}{4} + \frac{\pi(1.1D^2)\ d}{4}\right] \\ &= n \times EF \times \frac{\pi D^2 d}{4} (0.9^2 + 1.1^2) \\ &= n \times EF \times Q\ (0.9^2 + 1.1^2) \\ &= n \times EF \times Q \times 2.02 \end{aligned} \qquad (6\text{-}25)$$

The ratio of true emissions to those calculated from an emission factor based on an average diameter is 2.01/2.02 or 0.995, i.e., about a 0.5 percent error.

If the diameters of the two tank groups are 0.5 and 1.5 of the average diameter, the true to indicated emission is 2.318/2.506 or 0.927, i.e., about a 7.3 percent error.

A similar comparison is made for tank depth:

$$\begin{aligned} E &= \frac{K}{(0.9d)^{0.49}} \times n \times 0.9\,Q + \frac{K}{(1.1d)^{0.49}} \times n\ 1.1\,Q \\ &= EF \times Q \times n \left(0.9^{0.51} + 1.1^{0.51}\right) \qquad (6\text{-}26) \\ &= 1.997 \times EF \times n \times Q \end{aligned}$$

The EPA equations then yield the following:

$$\begin{aligned} E &= EF \times Q \times n \times (0.90 + 1.10) \\ &= 2.00 \times EF \times Q \times n \end{aligned} \qquad (6\text{-}27)$$

The ratio of true to indicated emissions is 1.997/2.000 or 0.999, i.e., about a +0.1 percent error.

For the 0.5 and 1.5 depth ratios, the true to indicated emission ratio is 1.932/2.000 or 0.966, i.e., about a +3.4 percent error.

6.7 ERROR OF EMISSION FACTORS BASED ON API ANALYSIS

The API equations for vapor loss from petroleum tanks express the emissions as functions of several independent variables to a variety of powers. These equations are given in Section 6.5.

The effect of calculating the emissions from a system of tanks while using a value different from the effective or true value of certain variables is presented in Tables 6-5 through 6-8 and in Figures 6-1 through 6-4 for fixed-roof breathing losses. The API equation for fixed-roof breathing losses is as follows:

$$L_y = C\left(\frac{P}{14.7 - P}\right)^{0.68} D^{1.73} H^{0.51} \Delta T^{0.5} F_p \qquad (6\text{-}28)$$

The symbols and terms used in Eq. (6-28) and in Tables 6-5 through 6-8 are defined in Section 6.5.

6.8 REFERENCES

6-1. S. Cheung, et al., "Computer Analysis of NEDS Point Source Emission Data," Contractor Magnetic Tape No. 74362, The Aerospace Corporation, El Segundo, California (Log date, November 10, 1975).

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Table 6-5. VAPOR PRESSURE EFFECTS ON FIXED-ROOF BREATHING LOSSES

Vapor Pressure P_i^a	$\left(P/14.7 - P\right)^{0.68}$	Ratio of Emissions E_i/E_B (Case of Interest ÷ Baseline Case)[a]			
		$P_B = 1$	$P_B = 2$	$P_B = 4$	$P_B = 6$
0.5	0.103	0.609			
1.0	0.169	1.000	0.593		
1.5	0.228	1.349	0.800		
2.0	0.285	1.686	1.000	0.557	
3.0	0.396		1.389	0.773	0.510
4.0	0.512		1.796	1.000	0.659
6.0	0.777			1.504	1.000
8.0	1.128			2.203	1.452

[a] Terms subscripted with "i" correspond to case of interest; terms subscripted with "B" correspond to baseline case.

Table 6-6. DIAMETER EFFECTS ON FIXED-ROOF BREATHING LOSSES

Diameter D_i[a]	C	$D^{1.73}$	$C \times D^{1.73}$	Ratio of Emissions E_i/E_B (Case of Interest ÷ Baseline Case)[a]				
				$D_B = 10$	$D_B = 30$	$D_B = 60$	$D_B = 110$	$D_B = 170$
6	0.30	22.19	6.66	0.248				
8	0.40	36.50	14.60	0.544				
10	0.50	53.70	26.85	1.000	0.075			
11	0.55	63.33	34.83	1.297	0.097			
12	0.60	73.62	44.17	1.645	0.123			
14	0.70	96.12	67.28	2.506	0.187			
20	0.88	178.15	156.77	5.839	0.436			
30	1.00	359.27	359.27		1.000	0.301		
40	1.00	590.97	590.97		1.645	0.496		
60	1.00	1191.80	1191.80			1.000	0.350	
80	1.00	1960.40	1960.40			1.645	0.576	
110	1.00	3401.02	3401.02			2.854	1.000	0.471
140	1.00	5161.80	5162.00				1.518	0.715
170	1.00	7222.32	7222.00				2.123	1.000
210	1.00	10409.73	10410.00					1.441
250	1.00	14074.60	14075.00					1.949

[a] Terms subscripted with "i" correspond to case of interest; terms subscripted with "B" correspond to baseline cases.

Table 6-7. ULLAGE DEPTH EFFECTS ON FIXED-ROOF BREATHING LOSSES

Ullage Depth H_i[a]	$H^{0.51}$	Ratio of Emissions E_i/E_B (Case of Interest ÷ Baseline Case)[a]			
		$H_B = 5$	$H_B = 10$	$H_B = 20$	$H_B = 25$
2	1.424	0.627			
3	1.751	0.771			
5	2.272	1.000	0.702		
7	2.698	1.188	0.834		
10	3.236	1.424	1.000	0.707	
15	3.979		1.230	0.863	0.771
20	4.603		1.424	1.000	0.892
25	5.164			1.121	1.000
30	5.667			1.230	1.097
35	6.130				1.187

[a] Terms subscripted with "i" correspond to case of interest; terms subscripted with "B" correspond to baseline cases.

Table 6-8. TEMPERATURE EXCURSION EFFECTS ON FIXED-ROOF BREATHING LOSSES

Temperature Excursion $\Delta T_i{}^a$	$\sqrt{T}$	Ratio of Emissions E_i/E_B (Case of Interest ÷ Baseline Case)[a]				
		$\Delta T_B = 5$	$\Delta T_B = 9$	$\Delta T_B = 15$	$\Delta T_B = 22$	$\Delta T_B = 30$
2	1.414	0.632				
5	2.236	1.000	0.745			
9	3.000	1.342	1.000	0.775		
15	3.873	1.732	1.291	1.000	0.826	
22	4.690		1.563	1.211	1.000	0.856
30	5.477			1.414	1.168	1.000
40	6.325				1.349	1.155
50						1.291

[a] Terms subscripted with "i" correspond to case of interest; terms subscripted with "B" correspond to baseline cases.

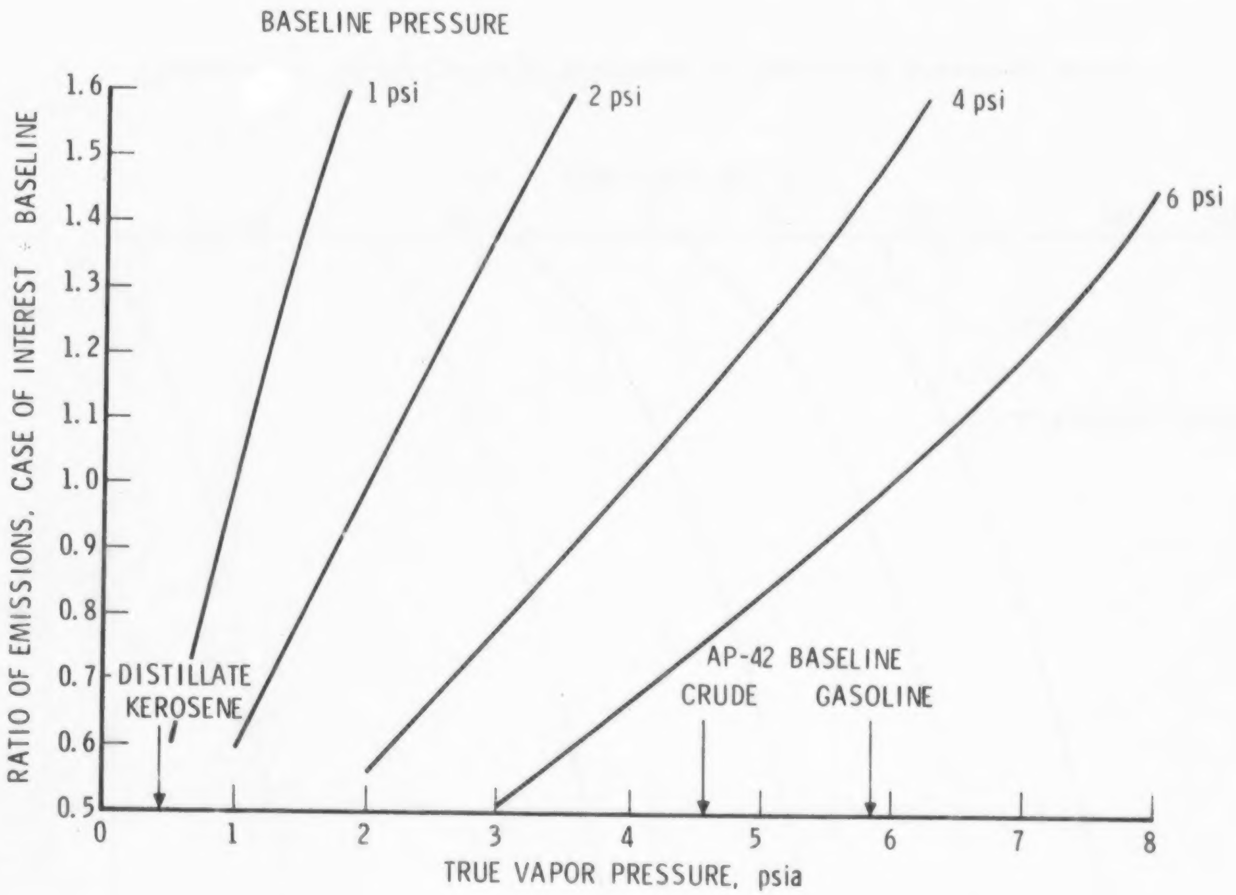

Figure 6-1. Effects of vapor pressure on fixed-roof breathing losses

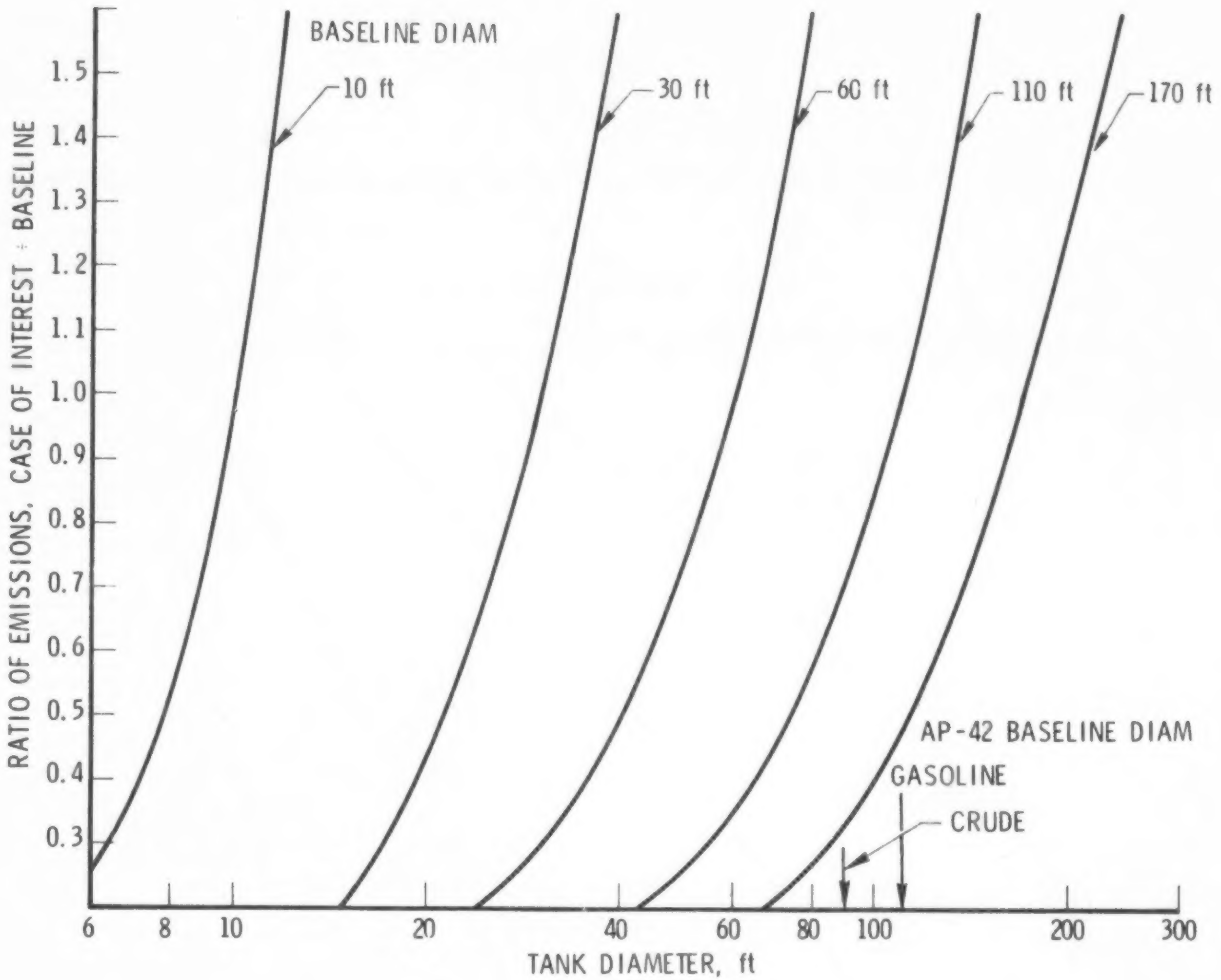

Figure 6-2. Effects of tank diameter on fixed-roof breathing losses

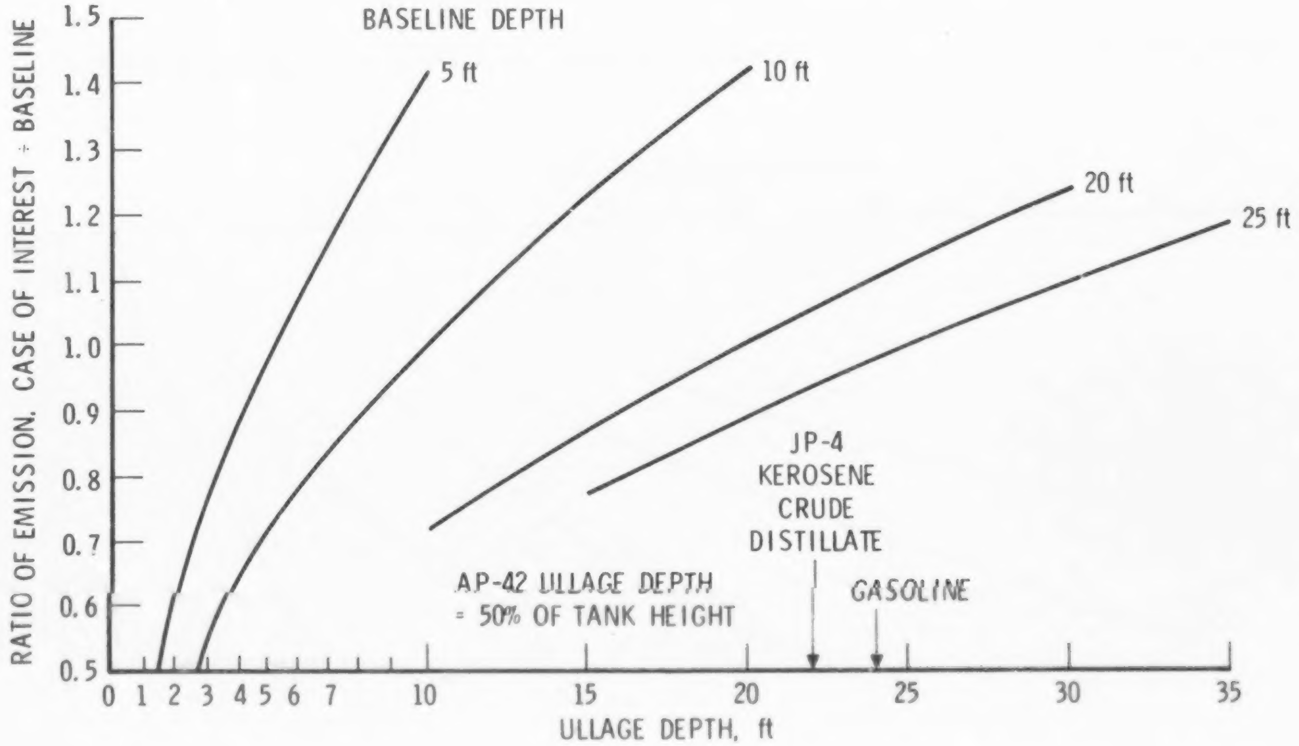

Figure 6-3. Effects of ullage depth on fixed-roof breathing losses

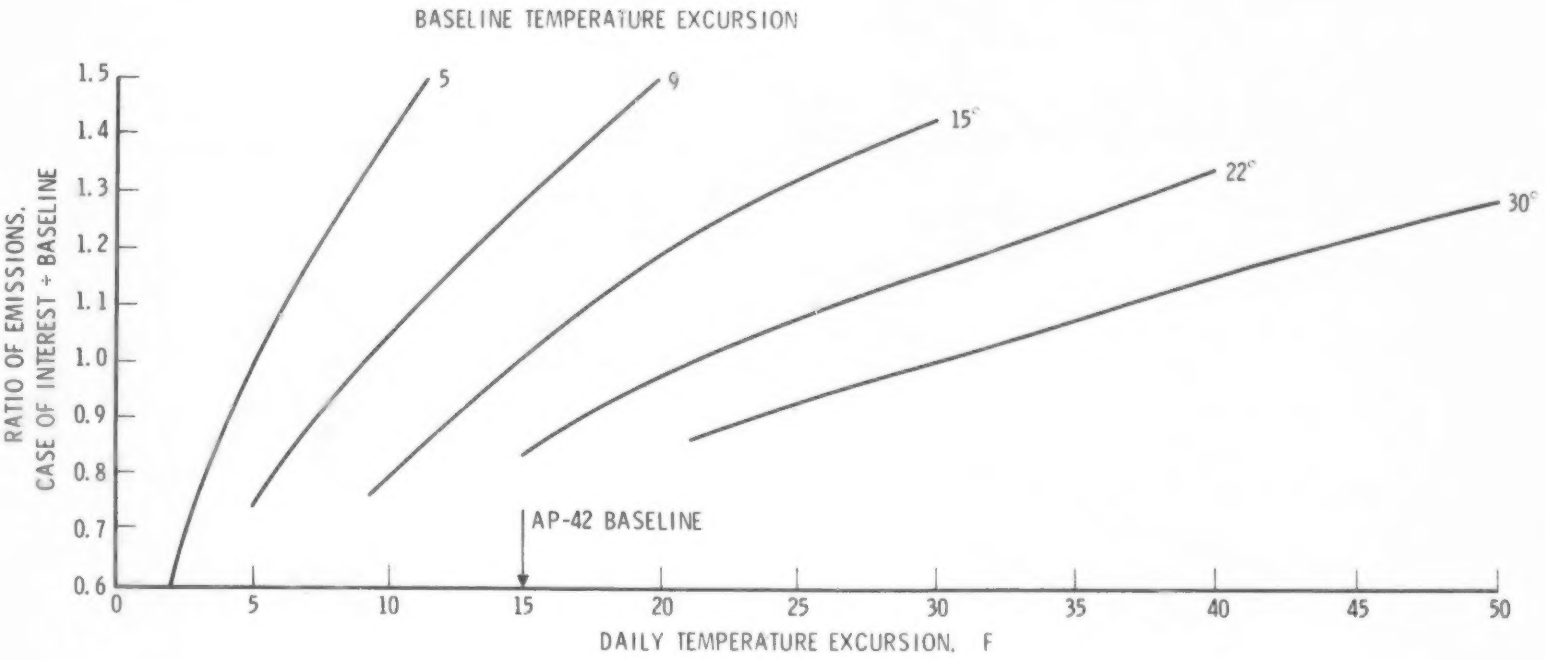

Figure 6-4. Effects of daily temperature excursion on fixed-roof breathing losses

SECTION VII

PRIMARY METALS

7.1 INTRODUCTION

The metallurgical industries are considered to be part of the industrial processes category of the National Emissions Data System (NEDS) source classification coding system. The primary metals industry uses ore for its production, while the secondary metals industry primarily uses scrap metal. The Source Classification Code (SCC) number which represents the primary metals industry is 3-03-xxx-xx.

Table 7-1 describes the metallurgical processes studied and gives the corresponding modified SCC (MSCC) numbers and annual charge (or usage) rate units. The study list was formed from those primary metal processes which had one or more of the four pollutants of interest with an emission rate greater than 500 tons/year according to Ref. 7-1. The four pollutants of interest in the study are oxides of nitrogen (NO_x), hydrocarbon (HC), carbon monoxide (CO), and particulate matter (PART). Except for a few isolated cases, the only significant quantities of emissions from the primary metals industry are CO and PART.

7.2 SUMMARY

The annual CO emissions from the primary metals industries in 1977 were 10.4 million tons compared to about 37.6 million tons from all stationary point sources. These are principally from blast furnaces (5.6 million tons) and basic oxygen furnaces (3.6 million tons) for pig iron and steel production. In 1982, the CO from primary metals is expected to be reduced to 5.7 million tons through the implementation of improved control techniques.

The PART emissions from the primary metals industry in 1977 were nearly 1.4-million tons. The estimated nationwide total PART emissions in 1975 from stationary point sources were 13.5-million tons.

The estimated 1982 PART emission rate from primary metals is 0.65-million tons. Most of this reduction is attributed to the improved control techniques which are forecast for copper smelters.

A detailed list of emissions and charge rate data for the two years of interest is shown in Tables 7-2-a and 7-3-a, and their uncertainties in Tables 7-2-b and 7-3-b.

7.3 PROCESSES EVALUATED

A total of 72 primary metal processes is listed in the NEDS data bank (Ref. 7-1). Fifty-two were found to show 500 or more tons of at least one of the four emissions of interest. Although the year of effectivity was between 1971 and 1973, these 52 categories were considered potential contributors to air pollution and therefore served as the basis for selection of the primary metal operations to be studied. A brief description of the most significant emitters of CO and PART follows.

7.3.1 Blast Furnace and Related Operations

Blast furnaces are used to produce pig iron by packing coke, iron ore, and limestone into brick-lined chamber. Much of the carbon is reacted to CO_2 (10 percent of blast furnace gas), but substantial quantities of CO (27 percent) are generated. From 1300 to 1800 lb of CO are generated for each ton of pig iron produced. Much of the CO produced is collected, cleaned of PART, and burned as a secondary fuel in the steel mill. Although the blast furnace gas (mostly CO) has a heat content of about 100 Btu/cu ft, its use as a fuel is secondary, in this study, to the emission control aspects of the burning.

(Continued on page 7-22)

Table 7-1. DEFINITION OF PRIMARY METALS PROCESSES

MSCC	Source Category	Charge Rate Unit
303001000	Aluminum electrode reduction	Aluminum, tons/yr
303001010	Prebake cells	Aluminum, tons/yr
303001020	Horizontal stud soderberg	Aluminum, tons/yr
303001030	Vertical stud soderberg	Aluminum, tons/yr
303001040	Materials handling	Aluminum, tons/yr
303001050	Anode bake furnace	Aluminum, tons/yr
303001990	Other, not classified	Aluminum, tons/yr
303002000	Aluminum ore calcined	Aluminum, tons/yr
303002010	General	Aluminum, tons/yr
303003000	Coke metallurgical byproduct	Coal, tons/yr
303003010	General	Coal, tons/yr
303003020	Oven charging	Coal, tons/yr
303003030	Oven pushing	Coal, tons/yr
303003040	Quenching	Coal, tons/yr
303003050	Unloading	Coal, tons/yr
303003990	Other, not classified	Coal, tons/yr
303004000	Coke beehive	Coal, tons/yr
303004010	General	Coal, tons/yr
303005000	Copper smelter	a
303005020	Roasting	Copper, tons/yr
303005030	Smelting	Copper, tons/yr
303005040	Converting	Copper, tons/yr
303005050	Refining	Copper, tons/yr
303005060	Ore crushing, material handling, and miscellaneous activity	Copper, tons/yr
303005990	Other, not classified	Ore, tons/yr

Table 7-1. DEFINITION OF PRIMARY METALS PROCESSES (Continued)

MSCC	Source Category	Charge Rate Unit
303006000	Ferroalloy production, open furnace	Produced, tons/yr
303006010	50% ferrosilicon	Produced, tons/yr
303006020	75% ferrosilicon	Produced, tons/yr
303006030	90% ferrosilicon	Produced, tons/yr
303006040	Silicon metal	Produced, tons/yr
303006050	Silicomanganese	Produced, tons/yr
303006990	Other, not classified	Produced, tons/yr
303007000	Ferroalloy production, semi-covered furnace	Produced, tons/yr
303007010	Ferromanganese	Produced, tons/yr
303007020	General	Produced, tons/yr
303008000	Iron production	a
303008010	Blast furnace charge	Produced, tons/yr
303008020	Blast furnace, agglomerates charge	Produced, tons/yr
303008030	Sintering general	Produced, tons/yr
303008040	Ore-crush, handle	Ore, tons/yr
303008050	Scarfing	Processed, tons/yr
303008060	Sand handling operation	Sand-baked, tons/yr
303008990	Other, not classified	Produced, tons/yr
303009000	Steel production	Produced, tons/yr
303009010	Openhearth noxlance	Produced, tons/yr
303009020	Openhearth noxlance	Produced, tons/yr
303009030	Basic oxygen furnace (general)	Produced, tons/yr
303009040	Electric arc with lance	Produced, tons/yr

Table 7-1. DEFINITION OF PRIMARY METALS PROCESSES (Continued)

MSCC	Source Category	Charge Rate Unit
303009050	Electric arc, no lance	Produced, tons/yr
303009990	Other, not classified	Produced, tons/yr
303010000	Lead smelters	a
303010010	Sintering	Ore, tons/yr
303010020	Blast furnace	Ore, tons/yr
303010990	Other, not classified	Ore, tons/yr
303011000	Molybdenum	a
303011010	Mining, general	Mined, 100 tons/yr
303011020	Milling, general	Product, tons/yr
303011990	Process, other	Processed, tons/yr
303012000	Titanium processes	a
303012010	Chlorination stat	Product, tons/yr
303030000	Zinc smelting	Processed, tons/yr
303030010	General	Processed, tons/yr
303030040	Horizontal retorts	Processed, tons/yr
303999000	Miscellaneous metallurgical operations	Processed, tons/yr
303999990	Not elsewhere classified	Produced, tons/yr

[a] This represents a collection of processes whose charge rate units are different from one another.

Table 7-2-a. 1977 PRIMARY METALS EMISSIONS AND CHARGE RATES

INDUSTRIAL PROCESS, PRIMARY METALS PAGE 1

ANNUAL CHARGE RATES AND EMISSIONS PROJECTED TO 1977 RUN DATE= NOV 16,1977

MODIFIED SCC	TACRF (SCC UNITS)	EMISSIONS (MILLIONS OF TONS / YEAR) NOX	HC	CO	PART
303000010	19840000.	NEG	NEG	NEG	.005
303001000	22338000.	NEG	NEG	NEG	.103
303001010	2508000.	NEG	NEG	NEG	.029
303001020	1132000.	NEG	NEG	NEG	.027
303001030	998000.	NEG	NEG	NEG	.011
303001040	3480000.	NEG	NEG	NEG	.005
303001050	1440000.	0.000	0.000	0.000	.000
303001990	12780000.	NEG	NEG	NEG	.030
303002000	9046000.	NEG	NEG	NEG	.037
303002010	9046000.	NEG	NEG	NEG	.037
303003000	458400000.	.002	.184	.056	.078
303003010	81900000.	.000	.061	.025	.003
303003020	81900000.	.001	.102	.025	.031
303003030	88000000.	NEG	.009	.003	.016
303003040	88000000.	NEG	NEG	NEG	.010
303003050	81900000.	NEG	NEG	NEG	.016
303003990	36700000.	NEG	.011	.004	.002
303004000	1390000.	NEG	.006	.001	.122
303004010	1390000.	NEG	.006	.001	.122
303005000		NEG	NEG	NEG	.340
303005020	125000.	NEG	NEG	NEG	.000
303005030	1654000.	NEG	NEG	NEG	.018
303005040	1654000.	NEG	NEG	NEG	.015
303005050	1654000.	NEG	NEG	NEG	.004
303005060	300000000.	NEG	NEG	NEG	.300
303005990	1654000.	NEG	NEG	NEG	.002
303006000	4292500.	NEG	NEG	NEG	.132

Table 7-2-a. 1977 PRIMARY METALS EMISSIONS AND CHARGE RATES (Continued)

INDUSTRIAL PROCESS, PRIMARY METALS PAGE 2

ANNUAL CHARGE RATES AND EMISSIONS PROJECTED TO 1977 RUN DATE= NOV 16,1977

MODIFIED SCC	TACRF (SCC UNITS)	EMISSIONS (MILLIONS OF TONS / YEAR) NOX	HC	CO	PART
303006010	77240.	NEG	NEG	NEG	.003
303006020	395000.	NEG	NEG	NEG	.020
303006030	312220.	NEG	NEG	NEG	.029
303006040	702000.	NEG	NEG	NEG	.073
303006050	96000.	NEG	NEG	NEG	.003
303006990	2710000.	NEG	NEG	NEG	.004
303007000	2520000.	NEG	NEG	NEG	.002
303007010	1000000.	NEG	NEG	NEG	.000
303007020	1520000.	NEG	NEG	NEG	.002
303008000		NEG	NEG	6.518	.418
303008010	80000000.	NEG	NEG	5.600	.048
303008020	80000000.	NEG	NEG	0.000	.017
303008030	51000000.	NEG	NEG	.918	.086
303008040	105400000.	NEG	NEG	NEG	.067
303008050	117000000.	NEG	NEG	NEG	.010
303008060	4400000.	NEG	NEG	NEG	.003
303008990	117000000.	NEG	NEG	NEG	.187
303009000	144630000.	.010	.008	3.835	.073
303009010	6500000.	NEG	NEG	0.000	.014
303009020	7700000.	NEG	NEG	0.000	.008
303009030	64000000.	NEG	NEG	3.552	.016
303009040	22100000.	NEG	NEG	.199	.012
303009050	6633000.	NEG	NEG	.060	.003
303009990	37700000.	.010	.008	.024	.020
303010000	6780000.	.000	.000	NEG	.007
303010010	790000.	NEG	NEG	NEG	.003
303010020	790000.	NEG	NEG	NEG	.003
303010990	5200000.	.000	.000	NEG	.001
303011000		NEG	NEG	NEG	.012

Table 7-2-a. 1977 PRIMARY METALS EMISSIONS AND CHARGE RATES (Continued)

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                    INDUSTRIAL PROCESS, PRIMARY METALS                    PAGE  3
ANNUAL CHARGE RATES AND EMISSIONS PROJECTED TO 1977     RUN DATE= NOV 16,1977
 MODIFIED         TACRF                 EMISSIONS (MILLIONS OF TONS / YEAR)
   SCC         (SCC UNITS)          NOX            HC             CO            PART

303011010     114000000.            NEG            NEG            NEG            .006
303011020      57500000.            NEG            NEG            NEG            .003
303011990     171000000.            NEG            NEG            NEG            .003

303012000         65000.            NEG            NEG            .002           NEG

303012010         65000.            NEG            NEG            .002           NEG

303030000       1554000.            NEG            NEG            NEG            .005

303030010        614000.            NEG            NEG            NEG            .003
303030040        940000.            NEG            NEG            NEG            .002

303999000      32000000.            .001           .001           .002           .048

303999990      32000000.            .001           .001           .002           .048
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Table 7-2-b. 1977 PRIMARY METALS UNCERTAINTIES

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                          INDUSTRIAL PROCESS, PRIMARY METALS                     PAGE  1
     TACRF AND EMISSION UNCERTAINTIES PROJECTED TO 1977         RUN DATE= NOV 16,1977
  MODIFIED          TACRF                EMISSIONS (MILLIONS OF TONS / YEAR)
    SCC          (SCC UNITS)           NOX            HC             CO            PART

 303000010    +     4230700.           NEG            NEG            NEG         +  .005
              -     4230700.           NEG            NEG            NEG         -  .005

 303001000    +     8849400.           NEG            NEG            NEG         +  .191
              -     3948800.           NEG            NEG            NEG         -  .042

 303001010    +      183100.           NEG            NEG            NEG         +  .025
              -      183100.           NEG            NEG            NEG         -  .026
 303001020    +     8000100.           NEG            NEG            NEG         +  .189
              -     1132000.           NEG            NEG            NEG         -  .027
 303001030    +       75392.           NEG            NEG            NEG         +  .007
              -       75392.           NEG            NEG            NEG         -  .011
 303001040    +      349860.           NEG            NEG            NEG         +  .004
              -      349860.           NEG            NEG            NEG         -  .005
 303001050    +      153850.       + 0.000        + 0.000        + 0.000         +  .000
              -      153850.       - 0.000        - 0.000        - 0.000         -  .000
 303001990    +     3758500.           NEG            NEG            NEG         +  .016
              -     3758500.           NEG            NEG            NEG         -  .016

 303002000    +      723290.           NEG            NEG            NEG         +  .029
              -      723290.           NEG            NEG            NEG         -  .037

 303002010    +      723290.           NEG            NEG            NEG         +  .029
              -      723290.           NEG            NEG            NEG         -  .037

 303003000    +    31887000.       +  .000        +  .021        +  .006         +  .034
              -    31887000.       -  .001        -  .064        -  .028         -  .035

 303003010    +    11893000.       +  .000        +  .011        +  .004         +  .002
              -    11893000.       -  .000        -  .033        -  .025         -  .002
 303003020    +    11893000.       +  .000        +  .018        +  .004         +  .031
              -    11893000.       -  .001        -  .054        -  .013         -  .031
 303003030    +    15435000.           NEG        +  .002        +  .001         +  .011
              -    15435000.           NEG        -  .005        -  .002         -  .012
 303003040    +    15435000.           NEG            NEG            NEG         +  .009
              -    15435000.           NEG            NEG            NEG         -  .010
 303003050    +    11893000.           NEG            NEG            NEG         +  .003
              -    11893000.           NEG            NEG            NEG         -  .003
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Table 7-2-b. 1977 PRIMARY METALS UNCERTAINTIES (Continued)

INDUSTRIAL PROCESS, PRIMARY METALS PAGE 2

TACR AND EMISSION UNCERTAINTIES PROJECTED TO 1977 RUN DATE= NOV 16,1977

MODIFIED SCC		TACRF (SCC UNITS)	NOX		HC		CO		PART
			EMISSIONS (MILLIONS OF TONS / YEAR)						
303003990	+	10770000.	NEG	+	.004	+	.001	+	.001
	-	10770000.	NEG	-	.004	-	.001	-	.001
303004000	+	135720.	NEG	+	.001	+	.000	+	.036
	-	135720.	NEG	-	.001	-	.000	-	.029
303004010	+	135720.	NEG	+	.001	+	.000	+	.036
	-	135720.	NEG	-	.001	-	.000	-	.029
303005000			NEG		NEG		NEG	+	.053
			NEG		NEG		NEG	-	.056
303005020	+	453980.	NEG		NEG		NEG	+	.001
	-	125000.	NEG		NEG		NEG	-	.000
303005030	+	170000.	NEG		NEG		NEG	+	.012
	-	170000.	NEG		NEG		NEG	-	.018
303005040	+	170000.	NEG		NEG		NEG	+	.012
	-	170000.	NEG		NEG		NEG	-	.015
303005050	+	170000.	NEG		NEG		NEG	+	.002
	-	170000.	NEG		NEG		NEG	-	.003
303005060	+	40361000.	NEG		NEG		NEG	+	.050
	-	40361000.	NEG		NEG		NEG	-	.050
303005990	+	170000.	NEG		NEG		NEG	+	.002
	-	170000.	NEG		NEG		NEG	-	.002
303006000	+	1056600.	NEG		NEG		NEG	+	.119
	-	1055800.	NEG		NEG		NEG	-	.081
303006010	+	16230.	NEG		NEG		NEG	+	.002
	-	16230.	NEG		NEG		NEG	-	.002
303006020	+	84152.	NEG		NEG		NEG	+	.013
	-	84152.	NEG		NEG		NEG	-	.020
303006030	+	9595.	NEG		NEG		NEG	+	.017
	-	9595.	NEG		NEG		NEG	-	.028
303006040	+	314010.	NEG		NEG		NEG	+	.051
	-	314010.	NEG		NEG		NEG	-	.073
303006050	+	104400.	NEG		NEG		NEG	+	.004
	-	96000.	NEG		NEG		NEG	-	.003

Table 7-2-b. 1977 PRIMARY METALS UNCERTAINTIES (Continued)

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                     INDUSTRIAL PROCESS, PRIMARY METALS                    PAGE  3
TACR AND EMISSION UNCERTAINTIES PROJECTED TO 1977        RUN DATE= NOV 16,1977
 MODIFIED           TACRF              EMISSIONS (MILLIONS OF TONS / YEAR)
   SCC           (SCC UNITS)         NOX          HC          CO          PART
303006990    +       999680.         NEG          NEG         NEG      +  .105
             -       999680.         NEG          NEG         NEG      -  .004

303007000    +       641890.         NEG          NEG         NEG      +  .002
             -       641890.         NEG          NEG         NEG      -  .002

303007010    +       215410.         NEG          NEG         NEG      +  .000
             -       215410.         NEG          NEG         NEG      -  .000
303007020    +       604670.         NEG          NEG         NEG      +  .002
             -       604670.         NEG          NEG         NEG      -  .002

303008000                            NEG          NEG      + 1.151     +  .247
                                     NEG          NEG      - 1.151     -  .222

303008010    +      9329500.         NEG          NEG      + 1.107     +  .025
             -      9329500.         NEG          NEG      - 1.107     -  .048
303008020    +      9329500.         NEG          NEG      + 0.000     +  .009
             -      9329500.         NEG          NEG      - 0.000     -  .017
303008030    +     13000000.         NEG          NEG      +  .315     +  .083
             -     13000000.         NEG          NEG      -  .315     -  .086
303008040    +     47539000.         NEG          NEG         NEG      +  .078
             -     47539000.         NEG          NEG         NEG      -  .067
303008050    +     21190000.         NEG          NEG         NEG      +  .021
             -     21190000.         NEG          NEG         NEG      -  .010
303008060    +       763220.         NEG          NEG         NEG      +  .001
             -       763220.         NEG          NEG         NEG      -  .001
303008990    +     21190000.         NEG          NEG         NEG      +  .216
             -     21190000.         NEG          NEG         NEG      -  .187

303009000    +     14310000.   +  .002     +  .002     + 1.085     +  .031
             -     14310000.   -  .010     -  .008     - 1.086     -  .033

303009010    +      5055900.         NEG          NEG      + 0.000     +  .017
             -      5055900.         NEG          NEG      - 0.000     -  .014
303009020    +      6062800.         NEG          NEG      + 0.000     +  .010
             -      6062800.         NEG          NEG      - 0.000     -  .008
303009030    +      7443100.         NEG          NEG      + 1.084     +  .009
             -      7443100.         NEG          NEG      - 1.084     -  .016
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Table 7-2-b. 1977 PRIMARY METALS UNCERTAINTIES (Continued)

INDUSTRIAL PROCESS, PRIMARY METALS PAGE 4

TACR AND EMISSION UNCERTAINTIES PROJECTED TO 1977 RUN DATE= NOV 16,1977

MODIFIED SCC	TACRP (SCC UNITS)	EMISSIONS (MILLIONS OF TONS / YEAR) NOX	HC	CO	PART
303009040	+ 5092200.	NEG	NEG	+ .051	+ .011
	- 5092200.	NEG	NEG	- .065	- .012
303009050	+ 680070.	NEG	NEG	+ .009	+ .003
	- 680070.	NEG	NEG	- .015	- .003
303009990	+ 7772300.	+ .002	+ .002	+ .006	+ .019
	- 7772300.	- .010	- .008	- .024	- .020
303010000	+ 1116500.	+ .000	+ .000	NEG	+ .003
	- 1116500.	- .000	- .000	NEG	- .005
303010010	+ 122070.	NEG	NEG	NEG	+ .002
	- 122070.	NEG	NEG	NEG	- .003
303010020	+ 122070.	NEG	NEG	NEG	+ .003
	- 122070.	NEG	NEG	NEG	- .003
303010990	+ 1103100.	+ .000	+ .000	NEG	+ .000
	- 1103100.	- .000	- .000	NEG	- .000
303011000		NEG	NEG	NEG	+ .003
		NEG	NEG	NEG	- .004
303011010	+ 17205000.	NEG	NEG	NEG	+ .002
	- 17205000.	NEG	NEG	NEG	- .002
303011020	+ 8602300.	NEG	NEG	NEG	+ .002
	- 8602300.	NEG	NEG	NEG	- .003
303011990	+ 25807000.	NEG	NEG	NEG	+ .001
	- 25807000.	NEG	NEG	NEG	- .001
303012000	+ 11661.	NEG	NEG	+ .002	NEG
	- 11661.	NEG	NEG	- .001	NEG
303012010	+ 11661.	NEG	NEG	+ .002	NEG
	- 11661.	NEG	NEG	- .001	NEG
303030000	+ 219140.	NEG	NEG	NEG	+ .002
	- 219140.	NEG	NEG	NEG	- .002
303030010	+ 108170.	NEG	NEG	NEG	+ .001
	- 108170.	NEG	NEG	NEG	- .001

Table 7-2-b. 1977 PRIMARY METALS UNCERTAINTIES (Continued)

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                          INDUSTRIAL PROCESS, PRIMARY METALS                  PAGE  5
TACR AND EMISSION UNCERTAINTIES PROJECTED TO 1977      RUN DATE= NOV 16,1977
 MODIFIED           TACRP                  EMISSIONS (MILLIONS OF TONS / YEAR)
   SCC          (SCC UNITS)          NOX            HC             CO          PART
303030040    +     190590.           NEG            NEG            NEG        +  .001
             -     190590.           NEG            NEG            NEG        -  .001
303999000    +    5000000.        +  .000        +  .000        +  .000       +  .009
             -    5000000.        -  .001        -  .001        -  .001       -  .009
303999990    +    5000000.        +  .000        +  .000        +  .000       +  .009
             -    5000000.        -  .001        -  .001        -  .001       -  .009
```

Table 7-3-a. 1982 PRIMARY METALS EMISSIONS AND CHANGE RATES

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                          INDUSTRIAL PROCESS, PRIMARY METALS                   PAGE  1
ANNUAL CHARGE RATES AND EMISSIONS PROJECTED TO 1982     RUN DATE= NOV 16,1977
  MODIFIED        TACRF              EMISSIONS (MILLIONS OF TONS / YEAR)
    SCC        (SCC UNITS)        NOX           HC            CO            PART
303000010       20740000.          NEG           NEG           NEG           .001

303001000       23618000.          NEG           NEG           NEG           .027

303001010        2593000.          NEG           NEG           NEG           .011
303001020        1172000.          NEG           NEG           NEG           .010
303001030        1033000.          NEG           NEG           NEG           .004
303001040        3630000.          NEG           NEG           NEG           .000
303001050        1510000.        0.000         0.000         0.000           .000
303001990       13680000.          NEG           NEG           NEG           .000

303002000        9456000.          NEG           NEG           NEG           .009

303002010        9456000.          NEG           NEG           NEG           .009

303003000      458400000.         .002          .184          .056           .024

303003010       81900000.         .000          .061          .025           .000
303003020       81900000.         .001          .102          .025           .001
303003030       88000000.          NEG          .009          .003           .005
303003040       88000000.          NEG           NEG           NEG           .000
303003050       81900000.          NEG           NEG           NEG           .016
303003990       36700000.          NEG          .011          .004           .001

303004000        1390000.          NEG          .006          .001           .042

303004010        1390000.          NEG          .006          .001           .042

303005000                          NEG           NEG           NEG           .312

303005020              0.        0.000         0.000         0.000         0.000
303005030        1654000.          NEG           NEG           NEG           .009
303005040        1654000.          NEG           NEG           NEG           .002
303005050        1654000.          NEG           NEG           NEG           .001
303005060      300000000.          NEG           NEG           NEG           .300
303005990        1654000.          NEG           NEG           NEG           .000

303006000        4086000.          NEG           NEG           NEG           .022
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Table 7-3-a. 1982 PRIMARY METALS EMISSIONS AND CHARGE RATES (Continued)

INDUSTRIAL PROCESS, PRIMARY METALS PAGE 2

ANNUAL CHARGE RATES AND EMISSIONS PROJECTED TO 1982 RUN DATE= NOV 16,1977

MODIFIED SCC	TACRF (SCC UNITS)	EMISSIONS (MILLIONS OF TONS / YEAR) NOX	HC	CO	PART
303006010	90940.	NEG	NEG	NEG	.001
303006020	465000.	NEG	NEG	NEG	.004
303006030	319070.	NEG	NEG	NEG	.005
303006040	462000.	NEG	NEG	NEG	.011
303006050	39000.	NEG	NEG	NEG	.000
303006990	2710000.	NEG	NEG	NEG	.000
303007000	2720000.	NEG	NEG	NEG	.001
303007010	1200000.	NEG	NEG	NEG	.000
303007020	1520000.	NEG	NEG	NEG	.001
303008000		NEG	NEG	4.008	.125
303008010	80000000.	NEG	NEG	3.600	.048
303008020	80000000.	NEG	NEG	0.000	.017
303008030	51000000.	NEG	NEG	.408	.032
303008040	76400000.	NEG	NEG	NEG	.008
303008050	117000000.	NEG	NEG	NEG	.002
303008060	4400000.	NEG	NEG	NEG	.001
303008990	117000000.	NEG	NEG	NEG	.018
303009000	136670000.	.010	.008	1.651	.019
303009010	0.	0.000	0.000	0.000	0.000
303009020	0.	0.000	0.000	0.000	0.000
303009030	64000000.	NEG	NEG	1.312	.016
303009040	28100000.	NEG	NEG	.253	.002
303009050	6866000.	NEG	NEG	.062	.000
303009990	37700000.	.010	.008	.024	.001
303010000	6970000.	.000	.000	NEG	.004
303010010	885000.	NEG	NEG	NEG	.001
303010020	885000.	NEG	NEG	NEG	.003
303010990	5200000.	.000	.000	NEG	.000
303011000		NEG	NEG	NEG	.006

Table 7-3-a. 1982 PRIMARY METALS EMISSIONS AND CHARGE RATES (Continued)

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                        INDUSTRIAL PROCESS, PFIMARY METALS                       PAGE   3
ANNUAL CHARGE RATES ANC EMISSIONS PROJECTEC TO 1982      RUN DATE= NOV 16,1977
 MODIFIED          TACRP                EMISSIONS (MILLIONS OF TONS / YEAR)
   SCC          (SCC UNITS)        NOX            HC            CO            PAFT

303011010       124000000.         NEG           NEG           NEG           .003
303011020        62500000.         NEG           NEG           NEG           .001
303011990       136000000.         NEG           NEG           NEG           .002

303012000           65000.         NEG           NEG          .000            NEG

303012010           65000.         NEG           NEG          .000            NEG

303030000         1554000.         NEG           NEG           NEG           .001

303030010          614000.         NEG           NEG           NEG           .000
303030040          940000.         NEG           NEG           NEG           .001

303999000        36000000.        .002          .001          .002           .054

303999990        36000000.        .002          .001          .002           .054
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Table 7-3-b. 1982 PRIMARY METALS UNCERTAINTIES

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                     INDUSTRIAL PROCESS, PRIMARY METALS                         PAGE  1
TACR AND EMISSION UNCERTAINTIES PROJECTED TO 1982       RUN DATE= NOV 16,1977
 MODIFIED          TACRF               EMISSIONS (MILLIONS OF TONS / YEAR)
   SCC          (SCC UNITS)         NOX             HC             CO          PART

303000010   +     4295200.          NEG            NEG            NEG        +  .001
            -     4295200.          NEG            NEG            NEG        -  .001

303001000   +     9010200.          NEG            NEG            NEG        +  .072
            -     4307300.          NEG            NEG            NEG        -  .016

303001010   +      228710.          NEG            NEG            NEG        +  .011
            -      228710.          NEG            NEG            NEG        -  .011
303001020   +     8000300.          NEG            NEG            NEG        +  .071
            -     1172000.          NEG            NEG            NEG        -  .010
303001030   +       94175.          NEG            NEG            NEG        +  .001
            -       94175.          NEG            NEG            NEG        -  .004
303001040   +      445980.          NEG            NEG            NEG        +  .000
            -      445980.          NEG            NEG            NEG        -  .000
303001050   +      195880.    + 0.000        + 0.000        + 0.000        +  .000
            -      195880.    - 0.000        - 0.000        - 0.000        -  .000
303001990   +     4108600.          NEG            NEG            NEG        +  .000
            -     4108600.          NEG            NEG            NEG        -  .000

303002000   +      799700.          NEG            NEG            NEG        +  .008
            -      799700.          NEG            NEG            NEG        -  .009

303002010   +      799700.          NEG            NEG            NEG        +  .008
            -      799700.          NEG            NEG            NEG        -  .009

303003000   +    77846000.    +  .001        +  .048        +  .014        +  .009
            -    77846000.    -  .001        -  .120        -  .035        -  .009

303003010   +    31822000.    +  .000        +  .025        +  .010        +  .000
            -    31822000.    -  .000        -  .061        -  .025        -  .000
303003020   +    31822000.    +  .000        +  .041        +  .010        +  .000
            -    31822000.    -  .001        -  .102        -  .025        -  .001
303003030   +    36098000.          NEG      +  .004        +  .001        +  .006
            -    36098000.          NEG      -  .009        -  .003        -  .005
303003040   +    36098000.          NEG            NEG            NEG        +  .000
            -    36098000.          NEG            NEG            NEG        -  .000
303003050   +    31822000.          NEG            NEG            NEG        +  .007
            -    31822000.          NEG            NEG            NEG        -  .007
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Table 7-3-b. 1982 PRIMARY METALS UNCERTAINTIES (Continued)

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                    INDUSTRIAL PROCESS, PRIMARY METALS                     PAGE  2
TACR AND EMISSION UNCERTAINTIES PROJECTED TO 1982       RUN DATE= NOV 16,1977
 MODIFIED          TACRP                EMISSIONS (MILLIONS OF TONS / YEAR)
   SCC          (SCC UNITS)        NOX              HC              CO          PART

303003990   +   20396000.          NEG        +  .007        +  .002      +  .001
            -   20396000.          NEG        -  .009        -  .003      -  .001

303004000   +     166480.          NEG        +  .001        +  .000      +  .042
            -     166480.          NEG        -  .004        -  .000      -  .042

303004010   +     166480.          NEG        +  .001        +  .000      +  .042
            -     166480.          NEG        -  .004        -  .000      -  .042

303005000                          NEG           NEG            NEG       +  .084
                                   NEG           NEG            NEG       -  .084

303005020   +          0.      + 0.000        + 0.000        + 0.000      + 0.000
            -          0.      - 0.000        - 0.000        - 0.000      - 0.000
303005030   +     407920.          NEG           NEG            NEG       +  .007
            -     407920.          NEG           NEG            NEG       -  .009
303005040   +     407920.          NEG           NEG            NEG       +  .000
            -     407920.          NEG           NEG            NEG       -  .002
303005050   +     407920.          NEG           NEG            NEG       +  .001
            -     407920.          NEG           NEG            NEG       -  .001
303005060   +   78000000.          NEG           NEG            NEG       +  .084
            -   78000000.          NEG           NEG            NEG       -  .084
303005990   +     407920.          NEG           NEG            NEG       +  .000
            -     407920.          NEG           NEG            NEG       -  .000

303006000   +    1737000.          NEG           NEG            NEG       +  .020
            -    1704500.          NEG           NEG            NEG       -  .013

303006010   +      29716.          NEG           NEG            NEG       +  .000
            -      29716.          NEG           NEG            NEG       -  .001
303006020   +     154080.          NEG           NEG            NEG       +  .004
            -     154080.          NEG           NEG            NEG       -  .004
303006030   +      15862.          NEG           NEG            NEG       +  .005
            -      15862.          NEG           NEG            NEG       -  .005
303006040   +     534880.          NEG           NEG            NEG       +  .016
            -     462000.          NEG           NEG            NEG       -  .011
303006050   +     202240.          NEG           NEG            NEG       +  .001
            -      39000.          NEG           NEG            NEG       -  .000
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Table 7-3-b. 1982 PRIMARY METALS UNCERTAINTIES (Continued)

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                       INDUSTRIAL PROCESS, PRIMARY METALS                                PAGE  3
TACR AND EMISSION UNCERTAINTIES PROJECTED TO 1982            RUN DATE= NOV 16,1977
 MODIFIED           TACRF                  EMISSIONS (MILLIONS OF TONS / YEAR)
   SCC           (SCC UNITS)             NOX             HC              CO           PART
303006090    +     1632600.             NEG             NEG             NEG        +  .010
             -     1632600.             NEG             NEG             NEG        -  .000

303007000    +     1032700.             NEG             NEG             NEG        +  .001
             -     1032700.             NEG             NEG             NEG        -  .001

303007010    +      407920.             NEG             NEG             NEG        +  .000
             -      407920.             NEG             NEG             NEG        -  .000
303007020    +      949680.             NEG             NEG             NEG        +  .001
             -      948680.             NEG             NEG             NEG        -  .001

303008000                               NEG             NEG         + 2.765        +  .047
                                        NEG             NEG         - 1.519        -  .063

303008010    +    18608000.             NEG             NEG         + 2.665        +  .027
             -    18608000.             NEG             NEG         - 1.463        -  .048
303008020    +    18608000.             NEG             NEG         + 0.000        +  .009
             -    18608000.             NEG             NEG         - 0.000        -  .017
303008030    +    22561000.             NEG             NEG         +  .738        +  .030
             -    22561000.             NEG             NEG         -  .408        -  .032
303008040    +    62290000.             NEG             NEG             NEG        +  .010
             -    62290000.             NEG             NEG             NEG        -  .008
303008050    +    31627000.             NEG             NEG             NEG        +  .004
             -    31627000.             NEG             NEG             NEG        -  .002
303008060    +     1360100.             NEG             NEG             NEG        +  .001
             -     1360100.             NEG             NEG             NEG        -  .001
303008990    +    31627000.             NEG             NEG             NEG        +  .020
             -    31627000.             NEG             NEG             NEG        -  .018

303009000    +    22515000.         +  .004         +  .003         + 3.184        +  .010
             -    22515000.         -  .010         -  .008         - 1.329        -  .016

303009010    +           0.         + 0.000         + 0.000         + 0.000        + 0.000
             -           0.         - 0.000         - 0.000         - 0.000        - 0.000
303009020    +           0.         + 0.000         + 0.000         + 0.000        + 0.000
             -           0.         - 0.000         - 0.000         - 0.000        - 0.000
303009030    +    14760000.             NEG             NEG         + 3.182        +  .010
             -    14760000.             NEG             NEG         - 1.312        -  .016
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Table 7-3-b. 1982 PRIMARY METALS UNCERTAINTIES (Continued)

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                        INDUSTRIAL PROCESS, PRIMARY METALS                     PAGE  4
 TACR AND EMISSION UNCERTAINTIES PROJECTED TO 1982      RUN DATE= NOV 16,1977
  MODIFIED          TACRF                EMISSIONS (MILLIONS OF TONS / YEAR)
    SCC          (SCC UNITS)         NOX              HC              CO            PART

 303009040    +    10933000.         NEG              NEG         +  .102       +  .001
              -    10933000.         NEG              NEG         -  .204       -  .002
 303009050    +      788160.         NEG              NEG         +  .010       +  .000
              -      788160.         NEG              NEG         -  .044       -  .000
 303009990    +    12998000.     +  .004          +  .003         +  .009       +  .000
              -    12998000.     -  .010          -  .008         -  .024       -  .001

 303010000    +     1769700.     +  .000          +  .000            NEG        +  .003
              -     1769700.     -  .000          -  .000            NEG        -  .003

 303010010    +      211900.         NEG              NEG            NEG        +  .000
              -      211900.         NEG              NEG            NEG        -  .001
 303010020    +      211900.         NEG              NEG            NEG        +  .003
              -      211900.         NEG              NEG            NEG        -  .003
 303010990    +     1744100.     +  .000          +  .000            NEG        +  .000
              -     1744100.     -  .000          -  .000            NEG        -  .000

 303011000                           NEG              NEG            NEG        +  .003
                                     NEG              NEG            NEG        -  .003

 303011010    +    26000000.         NEG              NEG            NEG        +  .003
              -    26000000.         NEG              NEG            NEG        -  .003
 303011020    +    13000000.         NEG              NEG            NEG        +  .001
              -    13000000.         NEG              NEG            NEG        -  .001
 303011990    +    39000000.         NEG              NEG            NEG        +  .002
              -    39000000.         NEG              NEG            NEG        -  .002

 303012000    +       20880.         NEG              NEG         +  .003          NEG
              -       20880.         NEG              NEG         -  .000          NEG

 303012010    +       20880.         NEG              NEG         +  .003          NEG
              -       20880.         NEG              NEG         -  .000          NEG

 303030000    +      372780.         NEG              NEG            NEG        +  .001
              -      372780.         NEG              NEG            NEG        -  .001

 303030010    +      189740.         NEG              NEG            NEG        +  .000
              -      189740.         NEG              NEG            NEG        -  .000
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Table 7-3-b. 1982 PRIMARY METALS UNCERTAINTIES (Continued)

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                    INDUSTRIAL PROCESS, PRIMARY METALS                   PAGE  5
TACR AND EMISSION UNCERTAINTIES PROJECTED TO 1982       RUN DATE= NOV 16,1977
 MODIFIED         TACRF              EMISSIONS (MILLIONS OF TONS / YEAR)
   SCC         (SCC UNITS)        NOX              HC               CO              PART

303030040   +      320880.          NEG              NEG              NEG        +  .001
            -      320880.          NEG              NEG              NEG        -  .001

303999000   +     8544000.      +  .000         +  .000         +  .000         +  .014
            -     8544000.      -  .002         -  .001         -  .002         -  .014

303999990   +     8544000.      +  .000         +  .000         +  .000         +  .014
            -     8544000.      -  .002         -  .001         -  .002         -  .014
```

Although nearly 90 percent of the CO formed does get collected and burned, approximately 150 lb of CO per ton of pig iron escape to the atmosphere. Much of these losses occur during charging exercises, but some are lost through leaks and inadvertent bypass procedures. Most of the CO and PART lost to the atmosphere occurs during "slips." A slip is caused when a bridge of stock forms in the furnace just above the molten slag. The bridge eventually collapses after the material beneath moves downward far enough to remove its support. Accompanying the collapse of the bridge is a rush of blast furnace gas to the top of the furnace, creating a momentary high pressure condition. The dust and CO-laden gas escapes through relief valves and bleeder ports to the atmosphere. Closer control of charge material has helped to reduce the occurrence of slips. Also, the increased operating pressure of the furnace and dust collection system has reduced the frequency at which the relief valves are opened to dump the emissions into the atmosphere. Few improvements are expected in the collection of blast furnace gas without substantial costs. These costs may become acceptable if the CO could be used as a chemical reactant to produce a useful product such as methanol rather than to burn it as the low grade fuel.

According to Ref. 7-2, the blast furnace gas contains 7 to 30 grains of dust per standard cubic foot (scf). Before the gas can be effectively used as a fuel, the PART must be removed. The first stage of dust removal involves either a cyclone or settling chamber, which removes about 60 percent of the pollutant. The second stage is normally a wet scrubber, which removes about 90 percent of the remaining dust. The final stage typically is an electrostatic precipitator, which can remove 90 percent of the remaining solid emissions. The system yields a 99.6 percent overall efficiency of particle collection.

For the purpose of this inventory, the general sintering operation is considered to be a part of pig iron production. The sinter operation supplies the blast furnaces with pellets consisting of a mixture of concentrated iron ore and fine coal. This operation is also a major source of CO and PART emissions. Control techniques are much the same as for the blast furnace, i.e., a dust collection system consisting of cyclone separators and electrostatic precipitators.

7.3.2 Basic Oxygen Furnaces

The basic oxygen furnace (BOF) is used in producing steel from the molten pig iron from blast furnaces (70 percent) and from scrap metal (30 percent). Unlike the blast furnace, no fuel such as coke is added to the charge in the BOF. Instead, the carbon, silicon, and other impurities are oxidized by injecting a stream of oxygen toward the molten metal charge. The oxidized silicon, manganese, and phosphorus slip into the slag, but the oxidized carbon evolves as CO. Attempts at collection for future burning in waste heat boilers are hampered by PART removal and especially by the tendency to create an explosive atmosphere in the furnace exhaust system.

The furnace gas contains CO, which is generated at the rate of 120 to 160 lb/ton of steel produced. Usually, an excess of air is simply mixed with the CO and the mixture burned as a flare, instead of being cleaned and burned in waste heat boilers. This eliminates the possibility of an explosion within the exhaust system. The CO concentration after combustion is reduced to about 3 lb/ton of steel produced. The bulk of the CO emissions to the atmosphere results from leakages and failure to collect all of the furnace gas.

As much as 40 to 50 lb of PART are generated per ton of steel produced by the BOF. Reference 7-3 lists standards of performance which when implemented would limit the particulate emissions to undiluted 0.022 grains/scf from newly installed BOFs. The limits can be achieved with high energy venturi scrubbers.

7.3.3 Primary Copper Smelting and Refining

The yield is low for copper ore (about 0.005 percent according to Table 2 of Ref. 7-4). As a result, dust and PART are emitted simply because of the large quantity of ore that must be handled to produce the copper refined in the U.S. Four major processes in the smelting of copper are the primary sources of PART emissions.

The first process, roasting, is performed only on ores with high sulfur content. Other ores can be fed directly to the reverberator furnace. Recent improvements in furnace design may eliminate the need for roasting. The use of the older multiple hearth roasters has been phased out of some plants, according to Ref. 7-5. The roasters operate at low temperatures and consequently dust collection is easily managed without elaborate cooling equipment.

The second process takes place in the reverberatory furnace which melts the metal-bearing charge and forms the copper entrained matte stream. Approximately 50 percent of the PART is less than 37 μm; consequently, collection and recovery of dust from the furnace gas is difficult.

The third process occurs in the copper converter which accepts the molten matte from the reverberatory furnace. The function of the converter is to oxidize and remove iron and sulfur from the matte stream. About 80 percent of the particulate matte in the gas stream from the converter is large enough to settle out in the flue system. The remainder is processed through scrubbers, collectors, and electrostatic precipitators. Based on the per unit amount of concentrated ore entering the roaster or furnace, the emission factor of PART from the converter is the highest of any process in copper smelting.

Refining is the final process in copper production. This process enables copper products to meet the high purity specifications for many copper products.

7.4 EMISSIONS ANALYSIS

This section describes certain hypotheses, assumptions, and observations that were made in the process of establishing the data base on which the charge rate and emission rate calculations were made.

7.4.1 Blast Furnace and Related Operations

Although there is good agreement among technical sources regarding the quantities of CO generated in the blast furnaces used to produce pig iron, Ref. 7-6 lists a value of 1750 lb of CO per ton of iron for an emission factor. Since this is a value near the typical number reported as the total CO generated per ton of iron, this can be used as a representative emission factor only if no controls are in effect, i.e., if all of the CO generated is permitted to escape to the atmosphere.

In this analysis, an effective CO emission factor was derived from the NEDS data by dividing the CO emissions (in pounds) by the charge rate (in tons) from Ref. 7-1. Although CO is likely to escape to the atmosphere from the blast furnace during any of many operations including ore and agglomerate charging and especially during the "slips" described in Section 7.3.1, all of the CO emissions from blast furnaces in this study are grouped under MSCC 303008010, entitled Blast Furnace Ore Charging.

So that the emissions might be based on the latest data, the base line charge rates were extracted from Ref. 7-7.

7.4.2 Basic Oxygen Furnace

CO is generated in the basic oxygen furnace (BOF) at a rate of about 150 lb/ton of steel produced. Although this can be reduced to near zero (3 or 5 lb/ton) by flaring or another combustion process, energy conservation tends to motivate the use of CO in waste heat boilers. The collection and cleaning of PART, necessary before using the CO as a fuel, impose a potentially explosive atmosphere.

Both of these two techniques for combustion of the CO waste have undesirable features. No safe means of collecting and cleaning the gas has been demonstrated. It was assumed, therefore, that the effective emission factor in 1975 was the one that corresponded to uncontrolled conditions (139 lb/ton of steel). The effective emission factor, however, is expected to decrease linearly to near zero by 1985.

The 1977 CO emissions from the BOF are 3.6 million tons. In 1982, these will be reduced to 1.3 million tons. The associated large uncertainties are due primarily to the unknown element of time in developing a safe collection system.

7.4.3 Copper Smelters

Good data exist on production rates of refined copper. However, most emission factor data are based on raw or, more often, on concentrated ore (Ref. 7-6). The ratio of concentrated ore to refined copper is approximately 4.0, according to page 139 of Ref. 7-5. This is the ratio that was used in calculating the emissions from copper smelters and related operations. Production rates were extracted from Refs. 7-4, 7-5, and 7-7 to establish baseline charge rates and slopes.

The quantities of PART emissions generated in each operation are highly sensitive to such factors as the chemical composition of the copper matte, the temperature of the converter, the fineness of the charge, and the degree of agitation in charging. As a result, a high degree of uncertainty exists for the uncontrolled emission factor. Fifteen percent uncertainty was used in these analyses.

7.5 REFERENCES

7-1. "Computer Analysis of NEDS Point Source Emission Data," Contractor Magnetic Tape No. 74362, The Aerospace Corporation, El Segundo, California (log date November 10, 1975).

7-2. Control Techniques for Carbon Monoxide Emissions from Stationary Sources, U. S. Department of Housing, Education, and Welfare, Washington, D. C. (March 1970).

7-3. Background Information for Proposed New Source Performance Standards," Vol. 1, U. S. Environmental Protection Agency, Washington, D. C. (June 1973).

7-4. Minerals Yearbook 1972, U. S. Bureau of Mines, Washington, D. C. (1974).

7-5. Particulate Pollutant System Study, VI, Mass Emissions, PB-203 522, Midwest Research Institute, U. S. Environmental Protection Agency, Durham, North Carolina (May 1971).

7-6. Compilation of Air Pollutant Emission Factors, AP-42, 2nd ed. (and supplements), U. S. Environmental Protection Agency, Research Triangle Park, North Carolina (April 1973).

7-7. Survey of Current Business, U. S. Department of Commerce, Washington, D. C. (February 1976).

SECTION VIII

SECONDARY METALS

8.1 INTRODUCTION

The metallurgical industries are classified as part of the industrial processes category of the National Emissions Data System (NEDS). The primary metals industry (described in Section VII) uses ore for its production, while the secondary metals industry uses scrap metal.

This section describes the rationale and results of the analysis performed to determine the atmospheric emissions from the secondary metals industry. The NEDS Source Classification Code (SCC) number which represents the secondary metals industry is 3-04-xxx-xx.

Table 8-1 describes the secondary metallurgical processes studied and gives the corresponding Modified SCC (MSCC) numbers and the units of the annual charge (or usage) rate. The list of industries studied was formed from those secondary metal processes which had one or more of the four pollutants of interest with an emission rate of 500 or more tons per year. The four pollutants of interest in the study are oxides of nitrogen (NO_x), unburned hydrocarbons (HC), carbon monoxide (CO), and particulate matter (PART). Except for a few isolated cases, the only significant quantities of emission from the secondary metals industry are CO and PART.

A detailed list of emissions and charge rate data for the two years of interest is shown in Tables 8-2-a and 8-3-a and the associated uncertainties in Tables 8-2-b and 8-3-b.

(Continued on page 8-18)

Table 8-1. DEFINITION OF SECONDARY METAL PROCESSES

MSCC	Source Category	Charge Rate Unit
304001000	Aluminum Operation	Tons produced
304001010	Sweating furnace	Tons produced
304001020	Smelter-crucible	Tons produced
304001030	Smelter-reverberation furnace	Tons produced
304001040	Chlorination station	Tons produced
304001100	Foil rolling	Tons produced
304001200	Can manufacture	Tons produced
304001500	Aluminum operation - roll, draw, extrude	Tons produced
304001990	Miscellaneous activity	Tons produced
304002000	Brass/Bronze Melt	
304002020	Crucible furnace	Tons charge
304002030	Cupola furnace	Tons charge
304002040	Electric induction furnace	Tons charge
304002050	Reverberatory furnace	Tons charge
304002060	Rotary furnace	Tons charge
304002990	Miscellaneous activity	Tons produced

Table 8-1. DEFINITION OF SECONDARY METAL PROCESSES (Continued)

MSCC	Source Category	Charge Rate Unit
304003000	Gray Iron	
304003010	Cupola	Tons of charge
304003030	Electric induction furnace	Tons of charge
304003050	Annealing operation	Tons of charge
304003300	Miscellaneous casting fabrication	Tons processed
304003400	Grinding and cleaning	Tons processed
304003500	Sand handling - general	Tons handled
304003990	Miscellaneous activity	Tons of charge
304004000	Lead Smelting	
304004020	Reverberatory furnace	Tons metal charged
304004030	Blast (cupola) furnace	Tons metal charged
304004990	Miscellaneous activity	Tons processed
304006000	Magnesium	
304006990	Miscellaneous activity	Tons processed

Table 8-1. DEFINITION OF SECONDARY METAL PROCESSES (Continued)

MSCC	Source Category	Charge Rate Unit
304007000	Steel Foundry	
304007010	Electric arc furnace	Tons processed
304007020	Open hearth furnace	Tons processed
304007030	Open hearth oxygen lance	Tons processed
304007040	Heat treat furnace	Tons processed
304007990	Miscellaneous activity	Tons processed
304008000	Zinc	
304008050	Galvanizing kettles	Tons produced
304008060	Calcining kiln	Tons produced
304009000	Malleable Iron	
304009990	Miscellaneous activity	Tons charge
304010000	Nickel	
304010990	Miscellaneous activity	Tons processed

Table 8-1. DEFINITION OF SECONDARY METAL PROCESSES (Continued)

MSCC	Source Category	Charge Rate Unit
304020000	Furnace Electrodes	Tons processed
304020040	Bake furnaces	Tons processed
304050000	Miscellaneous casting and fabrication	
304050010	Not classified elsewhere	Tons produced
304999000	Miscellaneous secondary metal	
304999990	Not classified elsewhere	Tons produced

Table 8-2-a. 1977 SECONDARY METALS EMISSIONS AND CHARGE RATES

INDUSTRIAL PROCESS, SECONDARY METALS PAGE 1

ANNUAL CHARGE RATES AND EMISSIONS PROJECTED TO 1977 RUN DATE= NOV 16,1977

MODIFIED SCC	TACRP (SCC UNITS)	EMISSIONS (MILLIONS OF TONS / YEAR) NOX	HC	CO	PART
304001000	3812400.	.001	.003	NEG	.006
304001010	70231.	NEG	NEG	NEG	.000
304001020	136280.	NEG	NEG	NEG	.000
304001030	1145000.	.000	NEG	NEG	.001
304001040	338930.	NEG	NEG	NEG	.002
304001100	125280.	NEG	.001	NEG	NEG
304001200	38414.	NEG	.001	NEG	NEG
304001500	122500.	NEG	.001	NEG	NEG
304001990	1835700.	.001	.001	NEG	.003
304002000	451900.	.000	.000	NEG	.001
304002020	40000.	NEG	NEG	NEG	.000
304002030	34900.	NEG	NEG	NEG	.000
304002040	142000.	NEG	NEG	NEG	.000
304002050	79400.	NEG	NEG	NEG	.001
304002060	6600.	NEG	NEG	NEG	.000
304002990	149000.	.000	.000	NEG	.000
304003000	62197000.	.000	.002	.792	.034
304003010	12114000.	.000	NEG	.787	.026
304003030	1526400.	NEG	.000	0.000	.000
304003050	1119000.	NEG	NEG	.001	NEG
304003300	8350200.	NEG	NEG	NEG	.002
304003400	9334000.	NEG	.000	.001	.002
304003500	22232000.	NEG	NEG	.002	.001
304003990	7522000.	NEG	.002	NEG	.004
304004000	664790.	NEG	.000	NEG	.000
304004020	449000.	NEG	NEG	NEG	.000
304004030	146000.	NEG	NEG	NEG	.000
304004990	69790.	NEG	.000	NEG	NEG
304006000	19380.	NEG	NEG	.000	NEG

Table 8-2-a. 1977 SECONDARY METALS EMISSIONS AND CHARGE RATES (Continued)

INDUSTRIAL PROCESS, SECONDARY METALS PAGE 2

ANNUAL CHARGE RATES AND EMISSIONS PROJECTED TO 1977 RUN DATE= NOV 16,1977

MODIFIED SCC	TACRF (SCC UNITS)	EMISSIONS (MILLIONS OF TONS / YEAR) NOX	HC	CO	PART
304006990	18380.	NEG	NEG	.000	NEG
304007000	167470000.	.023	.004	.014	.104
304007010	39030000.	.004	NEG	.014	.025
304007020	19760000.	.000	NEG	NEG	.012
304007030	27680000.	0.000	NEG	NEG	.049
304007040	16230000.	.008	NEG	NEG	.001
304007990	64750000.	.012	.004	NEG	.016
304008000	570400.	NEG	.004	NEG	.002
304008050	478000.	NEG	.004	NEG	.000
304008060	92400.	NEG	NEG	NEG	.002
304009000	1090000.	NEG	NEG	.008	.000
304009990	1090000.	NEG	NEG	.008	.000
304010000	14700.	NEG	NEG	.001	NEG
304010990	14700.	NEG	NEG	.001	NEG
304020000	275850.	NEG	NEG	NEG	.000
304020040	275850.	NEG	NEG	NEG	.000
304050000	1448400.	NEG	.001	NEG	.001
304050010	1448400.	NEG	.001	NEG	.001
304999000	11080000.	.002	.002	NEG	.010
304999990	11080000.	.002	.002	NEG	.010

Table 8-2-b. 1977 SECONDARY METALS UNCERTAINTIES

INDUSTRIAL PROCESS, SECONDARY METALS PAGE 1

TACR AND EMISSION UNCERTAINTIES PROJECTED TO 1977 RUN DATE= NOV 16,1977

MODIFIED SCC		TACRF (SCC UNITS)	EMISSIONS (MILLIONS OF TONS / YEAR) NOX	HC	CO	PART
304001000	+	116990.	+ .000	+ .000	NEG	+ .001
	-	116990.	- .000	- .001	NEG	- .001
304001010	+	3583.	NEG	NEG	NEG	+ .000
	-	3583.	NEG	NEG	NEG	- .000
304001020	+	6888.	NEG	NEG	NEG	+ .000
	-	6888.	NEG	NEG	NEG	- .000
304001030	+	61032.	+ .000	NEG	NEG	+ .000
	-	61032.	- .000	NEG	NEG	- .001
304001040	+	16621.	NEG	NEG	NEG	+ .000
	-	16621.	NEG	NEG	NEG	- .000
304001100	+	6880.	NEG	+ .000	NEG	NEG
	-	6880.	NEG	- .000	NEG	NEG
304001200	+	1953.	NEG	+ .000	NEG	NEG
	-	1953.	NEG	- .000	NEG	NEG
304001500	+	6103.	NEG	+ .000	NEG	NEG
	-	6103.	NEG	- .000	NEG	NEG
304001990	+	97652.	+ .000	+ .000	NEG	+ .001
	-	97652.	- .000	- .000	NEG	- .001
304002000	+	24625.	+ .000	+ .000	NEG	+ .001
	-	24625.	- .000	- .000	NEG	- .001
304002020	+	4304.	NEG	NEG	NEG	+ .000
	-	4304.	NEG	NEG	NEG	- .000
304002030	+	3773.	NEG	NEG	NEG	+ .000
	-	3773.	NEG	NEG	NEG	- .000
304002040	+	15264.	NEG	NEG	NEG	+ .000
	-	15264.	NEG	NEG	NEG	- .000
304002050	+	8575.	NEG	NEG	NEG	+ .000
	-	8575.	NEG	NEG	NEG	- .001
304002060	+	722.	NEG	NEG	NEG	+ .000
	-	722.	NEG	NEG	NEG	- .000
304002990	+	16326.	+ .000	+ .000	NEG	+ .000
	-	16326.	- .000	- .000	NEG	- .000
304003000	+	3073600.	+ .000	+ .000	+ .131	+ .019
	-	3073600.	- .000	- .001	- .131	- .021

Table 8-2-b. 1977 SECONDARY METALS UNCERTAINTIES (Continued)

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                         INDUSTRIAL PROCESS, SECONDARY METALS                        PAGE  2
TACR AND EMISSION UNCERTAINTIES PROJECTED TO 1977           RUN DATE= NOV 16,1977
 MODIFIED            TACRP                EMISSIONS (MILLIONS OF TONS / YEAR)
   SCC           (SCC UNITS)          NOX              HC              CO            PART
304003010    +     1261900.      +  .000             NEG        +  .131        +  .019
             -     1261900.      -  .000             NEG        -  .131        -  .021
304003030    +      159430.         NEG        +  .000        + 0.000        +  .000
             -      159430.         NEG        -  .000        - 0.000        -  .000
304003050    +      116430.         NEG             NEG        +  .002           NEG
             -      116430.         NEG             NEG        -  .000           NEG
304003300    +      865970.         NEG             NEG           NEG        +  .001
             -      865970.         NEG             NEG           NEG        -  .002
304003400    +      963540.         NEG        +  .000        +  .001        +  .001
             -      963540.         NEG        -  .000        -  .001        -  .002
304003500    +     2351900.         NEG             NEG        +  .001        +  .001
             -     2351900.         NEG             NEG        -  .001        -  .001
304003590    +      778270.         NEG        +  .000           NEG        +  .002
             -      778270.         NEG        -  .001           NEG        -  .003

304004000    +       27123.         NEG        +  .000           NEG        +  .000
             -       27123.         NEG        -  .000           NEG        -  .000

304004020    +       25455.         NEG             NEG           NEG        +  .000
             -       25455.         NEG             NEG           NEG        -  .000
304004030    +        8485.         NEG             NEG           NEG        +  .000
             -        8485.         NEG             NEG           NEG        -  .000
304004590    +        3962.         NEG        +  .000           NEG           NEG
             -        3962.         NEG        -  .000           NEG           NEG

304006000    +        1979.         NEG             NEG        +  .000           NEG
             -        1979.         NEG             NEG        -  .000           NEG

304006990    +        1979.         NEG             NEG        +  .000           NEG
             -        1979.         NEG             NEG        -  .000           NEG

304007000    +     6209800.      +  .003        +  .001        +  .011        +  .046
             -     6209800.      -  .009        -  .002        -  .004        -  .051

304007010    +     3000000.      +  .000             NEG        +  .011        +  .016
             -     3000000.      -  .002             NEG        -  .004        -  .025
304007020    +     1268200.      +  .000             NEG           NEG        +  .008
             -     1268200.      -  .000             NEG           NEG        -  .012
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Table 8-2-b. 1977 SECONDARY METALS UNCERTAINTIES (Continued)

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                    INDUSTRIAL PROCESS, SECONDARY METALS                    PAGE  3
TACR AND EMISSION UNCERTAINTIES PROJECTED TO 1977          RUN DATE= NOV 16,1977
 MODIFIED           TACRF                  EMISSIONS (MILLIONS OF TONS / YEAR)
   SCC           (SCC UNITS)         NOX           HC              CO            PART
304007030   +     2014100.      + 0.000            NEG            NEG        +  .039
            -     2014100.      - 0.000            NEG            NEG        -  .040
304007040   +     1181900.      +  .002            NEG            NEG        +  .001
            -     1181900.      -  .005            NEG            NEG        -  .001
304007990   +     4743400.      +  .002      +   .001             NEG        +  .016
            -     4743400.      -  .007      -   .002             NEG        -  .016

304008000   +       63268.         NEG       +   .001             NEG        +  .001
            -       63268.         NEG       -   .001             NEG        -  .002

304008050   +       60063.         NEG       +   .001             NEG        +  .000
            -       60063.         NEG       -   .001             NEG        -  .000
304008060   +       19882.         NEG             NEG            NEG        +  .001
            -       19882.         NEG             NEG            NEG        -  .002

304009000   +      171600.         NEG             NEG     +   .005          +  .000
            -      171600.         NEG             NEG     -   .005          -  .000

304009990   +      171600.         NEG             NEG     +   .005          +  .000
            -      171600.         NEG             NEG     -   .005          -  .000

304010000   +        4104.         NEG             NEG     +   .001             NEG
            -        4104.         NEG             NEG     -   .001             NEG

304010990   +        4104.         NEG             NEG     +   .001             NEG
            -        4104.         NEG             NEG     -   .001             NEG

304020000   +       59095.         NEG             NEG            NEG        +  .000
            -       59095.         NEG             NEG            NEG        -  .000

304020040   +       59095.         NEG             NEG            NEG        +  .000
            -       59095.         NEG             NEG            NEG        -  .000

304050000   +      345400.         NEG       +   .000             NEG        +  .001
            -      345400.         NEG       -   .001             NEG        -  .001

304050010   +      345400.         NEG       +   .000             NEG        +  .001
            -      345400.         NEG       -   .001             NEG        -  .001
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Table 8-2-b. 1977 SECONDARY METALS UNCERTAINTIES (Continued)

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                         INDUSTRIAL PROCESS, SECONDARY METALS                          PAGE  4
TACR AND EMISSION UNCERTAINTIES PROJECTED TO 1977            RUN DATE= NOV 16,1977
 MODIFIED             TACRP               EMISSIONS (MILLIONS OF TONS / YEAR)
   SCC             (SCC UNITS)          NOX             HC              CO            PART
304999000     +      2250000.       +  .001      +  .000          NEG         +  .005
              -      2250000.       -  .001      -  .001          NEG         -  .003
304999990     +      2250000.       +  .001      +  .000          NEG         +  .005
              -      2250000.       -  .001      -  .001          NEG         -  .003
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Table 8-3-a. 1982 SECONDARY METALS EMISSIONS AND CHARGE RATES

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                         INDUSTRIAL PROCESS, SECONDARY METALS                          PAGE  1
          ANNUAL CHARGE RATES AND EMISSIONS PROJECTED TO 1982      RUN DATE= NOV 16,1977
  MODIFIED          TACRF                EMISSIONS (MILLIONS OF TONS / YEAR)
    SCC          (SCC UNITS)         NOX            HC             CO             PART
 304001000         4222200.          .002           .003           NEG            .005

 304001010           77131.          NEG            NEG            NEG            .000
 304001020          151580.          NEG            NEG            NEG            .000
 304001030         1270000.          .000           NEG            NEG            .000
 304001040          370830.          NEG            NEG            NEG            .001
 304001100          140580.          NEG            .001           NEG            NEG
 304001200           42394.          NEG            .001           NEG            NEG
 304001500          135000.          NEG            .001           NEG            NEG
 304001990         2034700.          .001           .001           NEG            .004

 304002000          451900.          .000           .000           NEG            .000

 304002020           40000.          NEG            NEG            NEG            .000
 304002030           34900.          NEG            NEG            NEG            .000
 304002040          142000.          NEG            NEG            NEG            .000
 304002050           79400.          NEG            NEG            NEG            .000
 304002060            6600.          NEG            NEG            NEG            .000
 304002990          149000.          .000           .000           NEG            .000

 304003000        67542000.          .000           .002           .365           .017

 304003010        13164000.          .000           NEG            .362           .013
 304003030         1656400.          NEG            .000          0.000           .000
 304003050         1218000.          NEG            NEG            .000           NEG
 304003300         9065200.          NEG            NEG            NEG            .001
 304003400        10134000.          NEG            .000           .000           .001
 304003500        24132000.          NEG            NEG            .003           .000
 304003990         8172000.          NEG            .002           NEG            .001

 304004000          709440.          NEG            .000           NEG            .001

 304004020          479000.          NEG            NEG            NEG            .000
 304004030          156000.          NEG            NEG            NEG            .000
 304004990           74440.          NEG            .000           NEG            NEG

 304006000           21830.          NEG            NEG            .000           NEG
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Table 8-3-a. 1982 SECONDARY METALS EMISSIONS AND CHARGE RATES (Continued)

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                         INDUSTRIAL PROCESS, SECONDARY METALS                              PAGE  2
ANNUAL CHARGE RATES AND EMISSIONS PROJECTED TO 1982       RUN DATE= NOV 16,1977
 MODIFIED           TACRF                       EMISSIONS (MILLIONS OF TONS / YEAR)
   SCC           (SCC UNITS)           NOX              HC               CO              PART
304006990            21830.            NEG              NEG             .000              NEG

304007000        178420000.           .025             .004             .010             .038

304007010         41580000.           .004              NEG             .010             .003
304007020         21080000.           .003              NEG              NEG             .003
304007030         29480000.          0.000              NEG              NEG             .026
304007040         17260000.           .008              NEG              NEG             .000
304007990         69000000.           .012             .004              NEG             .005

304008000           570400.            NEG             .004              NEG             .000

304008050           478000.            NEG             .004              NEG             .000
304008060            92400.            NEG              NEG              NEG             .000

304009000          1090000.            NEG              NEG             .003             .000

304009990          1090000.            NEG              NEG             .003             .000

304010000            18950.            NEG              NEG             .000              NEG

304010990            18950.            NEG              NEG             .000              NEG

304020000           312350.            NEG              NEG              NEG             .000

304020040           312350.            NEG              NEG              NEG             .000

304050000          1628400.            NEG             .001              NEG             .000

304050010          1628400.            NEG             .001              NEG             .000

304999000         12580000.           .002             .002              NEG             .011

304999990         12580000.           .002             .002              NEG             .011
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Table 8-3-b. 1982 SECONDARY METALS UNCERTAINTIES

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                      INDUSTRIAL PROCESS, SECONDARY METALS                     PAGE  1
TACR AND EMISSION UNCERTAINTIES PROJECTED TO 1982       RUN DATE= NOV 16,1977
 MODIFIED          TACRP                  EMISSIONS (MILLIONS OF TONS / YEAR)
   SCC          (SCC UNITS)          NOX           HC             CO            PART
304001000    +     321100.     +  .000     +  .000           NEG      +  .003
             -     321100.     -  .001     -  .001           NEG      -  .001

304001010    +       9448.        NEG         NEG            NEG      +  .000
             -       9448.        NEG         NEG            NEG      -  .000
304001020    +      19961.        NEG         NEG            NEG      +  .000
             -      19961.        NEG         NEG            NEG      -  .000
304001030    +     167630.     +  .000        NEG            NEG      +  .000
             -     167630.     -  .000        NEG            NEG      -  .000
304001040    +      43286.        NEG         NEG            NEG      +  .001
             -      43286.        NEG         NEG            NEG      -  .001
304001100    +      19958.        NEG      +  .000           NEG         NEG
             -      19958.        NEG      -  .001           NEG         NEG
304001200    +       5364.        NEG      +  .000           NEG         NEG
             -       5364.        NEG      -  .001           NEG         NEG
304001500    +      16763.        NEG      +  .000           NEG         NEG
             -      16763.        NEG      -  .001           NEG         NEG
304001990    +     268210.     +  .000     +  .000           NEG      +  .003
             -     268210.     -  .001     -  .000           NEG      -  .001

304002000    +      79617.     +  .000     +  .000           NEG      +  .000
             -      79617.     -  .000     -  .000           NEG      -  .000

304002020    +      13708.        NEG         NEG            NEG      +  .000
             -      13708.        NEG         NEG            NEG      -  .000
304002030    +      12419.        NEG         NEG            NEG      +  .000
             -      12419.        NEG         NEG            NEG      -  .000
304002040    +      49729.        NEG         NEG            NEG      +  .000
             -      49729.        NEG         NEG            NEG      -  .000
304002050    +      27969.        NEG         NEG            NEG      +  .000
             -      27969.        NEG         NEG            NEG      -  .000
304002060    +       2304.        NEG         NEG            NEG      +  .000
             -       2304.        NEG         NEG            NEG      -  .000
304002990    +      52308.     +  .000     +  .000           NEG      +  .000
             -      52308.     -  .000     -  .000           NEG      -  .000

304003000    +   11808000.     +  .000     +  .001     +  .340     +  .011
             -   11808000.     -  .000     -  .002     -  .340     -  .013
```

Table 8-3-b. 1982 SECONDARY METALS UNCERTAINTIES (Continued)

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                          INDUSTRIAL PROCESS, SECONDARY METALS                                     PAGE  2
TACF AND EMISSION UNCERTAINTIES PROJECTED TO 1982                   RUN DATE= NOV 16,1977
MODIFIED           TACRF                  EMISSIONS (MILLIONS OF TONS / YEAR)
  SCC          (SCC UNITS)          NOX              HC               CO              PART
304003010   +    4850800.      +   .000            NEG          +   .340         +   .010
            -    4850800.      -   .000            NEG          -   .340         -   .013
304003030   +     608290.          NEG         +   .000         +  0.000         +   .000
            -     608290.          NEG         -   .000         -  0.000         -   .000
304003050   +     446360.          NEG             NEG          +   .003             NEG
            -     446360.          NEG             NEG          -   .000             NEG
304003300   +    3300600.          NEG             NEG              NEG          +   .001
            -    3300600.          NEG             NEG              NEG          -   .001
304003400   +    3687800.          NEG         +   .000         +   .003         +   .001
            -    3687800.          NEG         -   .000         -   .000         -   .001
304003500   +    9053800.          NEG             NEG          +   .001         +   .000
            -    9053800.          NEG             NEG          -   .002         -   .000
304003590   +    2976300.          NEG         +   .101             NEG          +   .001
            -    2976300.          NEG         -   .001             NEG          -   .001

304004000   +      54591.          NEG         +   .000             NEG          +   .000
            -      54591.          NEG         -   .000             NEG          -   .000

304004020   +      51264.          NEG             NEG              NEG          +   .000
            -      51264.          NEG             NEG              NEG          -   .000
304004030   +      17088.          NEG             NEG              NEG          +   .000
            -      17088.          NEG             NEG              NEG          -   .000
304004590   +       7762.          NEG         +   .000             NEG              NEG
            -       7762.          NEG         -   .000             NEG              NEG

304006000   +       5096.          NEG             NEG          +   .001             NEG
            -       5096.          NEG             NEG          -   .000             NEG

304006990   +       5096.          NEG             NEG          +   .001             NEG
            -       5096.          NEG             NEG          -   .000             NEG

304007000   +   10779000.      +   .004        +   .001         +   .020         +   .023
            -   10779000.      -   .014        -   .004         -   .001         -   .027

304007010   +    5366600.      +   .001            NEG          +   .020         +   .000
            -    5366600.      -   .004            NEG          -   .001         -   .003
304007020   +    2307900.      +   .000            NEG              NEG          +   .002
            -    2307900.      -   .000            NEG              NEG          -   .003
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Table 8-3-b. 1982 SECONDARY METALS UNCERTAINTIES (Continued)

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                        INDUSTRIAL PROCESS, SECONDARY METALS                          PAGE  3
TACR AND EMISSION UNCERTAINTIES PROJECTED TO 1982       RUN DATE= NOV 16,1977
 MODIFIEC        TACRF                 EMISSIONS (MILLIONS OF TONS / YEAR)
   SCC        (SCC UNITS)          NOX            HC              CO            PAFT
304007030  +    3344300.       + 0.000           NEG             NEG        +  .022
           -    3344300.       - 0.000           NEG             NEG        -  .026
304007040  +    1955100.       +  .002           NEG             NEG        +  .000
           -    1955100.       -  .007           NEG             NEG        -  .000
304007990  +    8188400.       +  .003       +  .001             NEG        +  .006
           -    8188400.       -  .011       -  .004             NEG        -  .005

304008000  +     133490.         NEG         +  .001             NEG        +  .000
           -     133490.         NEG         -  .003             NEG        -  .000

304008050  +     129210.         NEG         +  .001             NEG        +  .000
           -     129210.         NEG         -  .003             NEG        -  .000
304008060  +      33929.         NEG            NEG              NEG        +  .000
           -      33929.         NEG            NEG              NEG        -  .000

304009000  +     287310.         NEG            NEG          +  .010        +  .000
           -     287310.         NEG            NEG          -  .002        -  .000

304009990  +     287310.         NEG            NEG          +  .010        +  .000
           -     287310.         NEG            NEG          -  .002        -  .000

304010000  +       7988.         NEG            NEG          +  .002           NEG
           -       7988.         NEG            NEG          -  .000           NEG

304010990  +       7988.         NEG            NEG          +  .002           NEG
           -       7988.         NEG            NEG          -  .000           NEG

304020000  +      83200.         NEG            NEG              NEG        +  .000
           -      83200.         NEG            NEG              NEG        -  .000

304020040  +      83200.         NEG            NEG              NEG        +  .000
           -      83200.         NEG            NEG              NEG        -  .000

304050000  +     491050.         NEG         +  .000             NEG        +  .000
           -     491050.         NEG         -  .001             NEG        -  .000

304050010  +     491050.         NEG         +  .000             NEG        +  .000
           -     491050.         NEG         -  .001             NEG        -  .000
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Table 8-3-b. 1982 SECONDARY METALS UNCERTAINTIES (Continued)

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                    INDUSTRIAL PROCESS, SECONDARY METALS                 PAGE  4
TACR AND EMISSION UNCERTAINTIES PROJECTED TO 1982       RUN DATE= NOV 16,1977
 MODIFIED          TACRP              EMISSIONS (MILLIONS OF TONS / YEAR)
   SCC          (SCC UNITS)        NOX             HC             CO            PART

304999000    +    3370800.     +  .001      +  .001          NEG       +  .007
             -    3370800.     -  .002      -  .002          NEG       -  .004

304999990    +    3370800.     +  .001      +  .001          NEG       +  .007
             -    3370800.     -  .002      -  .002          NEG       -  .004
```

8.2 SUMMARY

Data in Tables 8-2-a and 8-3-a show that the vast majority of CO emissions (96 percent) from those processes grouped in the secondary metals category are emitted from the cupola furnace process used in gray iron production. Not only is the great majority of gray iron produced in the cupola furnace, but it is the only type of gray iron furnace which emits significant concentrations of CO. Other furnace types yield so little that CO emission factors have not even been defined. CO emissions from cupola furnaces can be controlled by afterburning. Reduction in CO emissions from cupola furnaces by about a factor of two are projected over the next five years.

More than half of the PART emissions from the secondary metals category result from a variety of furnaces and processes involved in a steel foundry, principally the open hearth oxygen lance process. Broader applications of particulate control equipment are expected to reduce PART emissions from steel foundaries by nearly a factor of three over the next five years.

8.3 PROCESSES EVALUATED

A total of 72 categories of secondary metal processes is listed in the NEDS data bank. Thirty-seven of these categories contributed 500 or more tons per year of at least one of the four emissions of interest. Although the year of effectivity was between 1971 and 1973, these 37 industries were considered potential contributors of significant quantities of pollution in 1977 and later. Thus the list of processes to be studied was formed. Metal for secondary melting comes from scrap, pigs, machine shaving or foundry returns, whereas primary metals come from ore. A brief description of processes which were responsible for the most significant quantities of emissions of CO and PART follows.

8.3.1 Gray Iron Foundries

The cupola, electric, and reverberatory furnaces are the types most widely used in gray iron production. Although there are other sources of pollution in the iron foundry, the furnaces are responsible for the preponderance of the CO and PART emissions. The cupola furnace is used to melt most of the secondary iron being produced today because of its adaptability to high production rates and moderate operating costs.

According to Ref. 8-1, as cupolas are being retired and where production rates permit, it has been more advantageous to substitute reverberatory furnaces rather than install the control equipment necessary for cupolas. The typical uncontrolled PART emission factors are, respectively, 17, 2, 5, and 1.5 $\frac{lb}{ton}$ for cupolas, reverberatory, electric arc, and electric induction furnaces. The electric furnaces are used primarily where special alloys are made and where rapid and accurate heat control is needed.

In addition to PART matter, the cupola generates about 145 lb of CO per ton of metal produced. Afterburners are frequently installed in cupola control systems. In addition to alleviating the CO pollution problem, afterburners eliminate the explosive environment of the cupola and reduce the concentration of combustible PART matter in the effluent.

A typical combustion gas analysis of a cupola before the afterburner is 12 percent CO_2, 11 percent CO, 1/2 percent O_2, and 76 percent N_2. Depending on dwell time, mixing effectiveness, and gas temperature, the CO concentration can be brought to near zero at the afterburner exit.

The reverberatory furnace also generates CO, but, because the products of combustion come in contact with molten metal, the CO is virtually all converted to CO_2 before leaving the furnace. Since no combustion (except for oil-laden scrap) takes place in the electric furnaces, no CO is generated here.

8.3.2 Secondary Aluminum Smelters

Secondary aluminum sources include (1) pigs or ingots, (2) foundry returns and machining chips, and (3) scrap. The first two types are relatively clean and can be dumped directly into the melting furnaces, which are primarily comprised of crucibles and reverberatory furnaces. The scrap metal, however, may be contaminated with foreign materials, including dirt, oil, paint, plastics, and other metals. Some of these contaminants can be removed by passing the scrap through a sweating furnace. These sweating furnaces are open-flame reverberatory type. The furnace operates at 1250 to 1400°F, which allows all aluminum to melt, combustibles to burn, and higher melting materials like iron, brass, and dross to remain intact. The aluminum flows into pig molds and is later remelted in one of the main furnaces. The primary source of air pollution from the sweating furnace includes the emissions from incomplete combustion of the organic materials, stray pieces of magnesium, and other materials such as the dross and skim.

According to Ref. 8-1, the main furnaces' fluxing is accomplished for one or more of the following reasons: (1) minimize aluminum oxidation, (2) form nucleus for impurity removal with dross skimming, (3) dissolve unwanted gases, and (4) reduce magnesium content. Pure aluminum charge needs little flux, while dirty scrap may require the charge to consist of as much as 1/3 flux. In addition to flux, magnesium content is reduced by use of chlorine gas. Extra precautions must be taken because of the high toxicity of the gas.

Both fluxing and chlorination cause particulate matter to be emitted from the furnaces. Some of the particulate matter includes magnesium and aluminum chlorides, fluorides, and oxides, along with various salts. Any control systems used to collect the particles must also deal with the toxic gases.

8.4 EMISSIONS ANALYSIS

This section describes the assumptions, hypotheses, and significant observations that were made in the course of defining the data base with which the charge rates and emission rate calculations were made.

8.4.1 Gray Iron Foundaries

Reference 8-2 lists the total shipments (orders filled) as 13.6 million tons of gray and ductile iron for the 12-month period ending August 1976. This value was used as the total production rate, i.e., the combined charge rate of cupola, reverberatory, and electric furnaces. This total charge rate was distributed among the three furnaces in the same proportions noted in NEDS. The total charge rate uncertainty was established as 0.81×10^6 ton/yr, which was the standard error of estimate based on several consecutive years of production listed in Ref. 8-4.

The variations in gray iron production from year to year was rather high according to data listed in Ref. 8-3. Therefore it was necessary to resort to techniques other than that of obtaining an average slope from actual production rate data. The slope of the production curve was set equal to 1.75 percent, which was the average rate of increase since 1967 in the "Index of Industrial Production," shown in Ref. 8-3, while the uncertainty of the slope was set equal to the standard deviation of the annual increase. The derived value was 6.3 percent of the total charge rate.

The activities peripheral to metal melting (furnaces), such as sand handling, grinding, casting, and fabrication, were defined in the same proportions (of the total iron production) as noted in NEDS data.

Emission factors were extracted from Ref. 8-5 when available, otherwise one was derived by dividing the NEDS emissions by the charge rate. Reference 8-6 data, when available, was used to substantiate other data, but because of its age (1971 report, 1968 measurements) it was not used as a primary source.

8.4.2 Secondary Aluminum Smelters

Unlike the gray iron foundries, the data for production in secondary aluminum smelters were somewhat discrepant and consequently were assigned larger uncertainties. Fortunately, Ref. 8-2 and 8-3 data, since 1972, agreed favorably. For 1967 and 1972, Ref. 8-7 data substantiated Ref. 8-2 data quite well; therefore the charge rate analysis was based on Ref. 8-2 data.

The crucible and reverberation furnaces combined charge rates are considered to represent the total secondary aluminum production (recovery from scrap) as listed in Ref. 8-2. The ratio of the charge rates of the various process categories to the sum of the charge rates of these two furnaces was assumed to be the same for today's production rates (Ref. 8-2) as for the values listed in NEDS.

The charge rate slopes were determined by least square fit of the charge rate data, and the uncertainty of charge rate was determined as the standard error of estimate. The slope uncertainties were set to 100 percent of the slope value.

Aluminum emission factor data were extracted from Ref. 8-5 when available; otherwise, a set of derived values was calculated from NEDS data.

8.5 REFERENCES

8-1. Air Pollution Engineering Manual, 2nd Edition, AP-40 U. S. Environmental Protection Agency, Research Triangle Park, North Carolina (May 1973); prepared by Los Angeles Air Pollution Control District.

8-2. Survey of Current Business (October 1976).

8-3. Metal Statistics (1976).

8-4. Air Pollution Aspects of the Iron Foundry Industry, A. T. Kearney (February 1971).

8-5. Compilation of Air Pollutant Emission Factors, AP-42. 2nd Edition (and supplements), U. S. Environmental Protection Agency, Research Triangle Park, North Carolina (April 1973).

8-6. Particulate Pollutant System Study, VI, Mass Emissions, PB-203 522, Midwest Research Institute, U. S. Environmental Protection Agency, Durham, North Carolina (May 1971).

8-7. 1972 Census of Manufacturers, Department of Commerce, Washington, D. C.

SECTION IX

MINERAL PRODUCTS

9.1 INTRODUCTION

The category of mineral products covers the processing of non-metallic minerals from the quarry or mine to a condition of a saleable product, typically, for the construction industry. The general types of processes concerned include size reduction (crushing or grinding), sorting (primarily screen operations, with some air classification steps), conveying (loaders, trucks, or conveyor belts), and storage (open, bin, or silo). For certain mineral products, there are important additional processes involving change in physical or chemical state. Examples of the former are blending, sintering, and pressing into desired shapes. The most prevalent type of chemical process consists of heating (often in a rotary kiln) to drive off water of hydration and/or to bring about a controlled degree of thermal decomposition (generally referred to as calcining). This latter process may be followed by additional sintering reactions which yield new chemical species.

The principal emission in virtually every case is particulate (PART) matter. Oxide of nitrogen (NO_x) emissions are relatively low and are primarily attributed to the fuel combustion processes involved. Hydrocarbon (HC) and carbon monoxide (CO) emissions are not significant. The PART, NO_x, HC and CO emissions assigned to the mineral products category in the November 15, 1976 National Emissions Data System (NEDS) summary report (prior to initiating this study) represented approximately 26, 2.4, 0.2, and 0.1 percent, respectively, of the total point source emissions of these pollutants. Among the NEDS major point source categories, the mineral products category was second only to utility boilers in terms of the percentage contribution of PART emissions to the nationwide total.

Based on the present work, the indicated particulate emissions from the mineral products category are substantially larger than indicated by the NEDS data of November 15, 1976, and mineral products now represent the largest source category of PART emissions.

Potentially large PART emissions may occur from each of the process operations mentioned. In those operations involving heating, PART emissions may also occur as a result of the fuel combustion process, but these are usually not significant in comparison to the particulates generated from the mineral product being processed. The chemical species involved in the PART emissions from the mineral products industry are usually not considered to be toxic but are of concern because of the high process tonnage rates and because of the small particle sizes (into the submicron range), which are often included in the emissions. These smaller particles may be transported long distances in the atmosphere and, if inhaled, may represent health hazards because of their tendency to bypass the natural body defenses against ingestion of foreign matter into the lungs.

9.2 SUMMARY

The categories of mineral products which were examined in this study are delineated in Table 9-1. The charge rates and emissions for each of the major process categories are listed in Tables 9-2-a and 9-3-a; the corresponding uncertainties of each of these parameters are given in Tables 9-2-b and 9-3-b.

The total rate of PART emissions for the mineral products industries is indicated as about 7.8 megatons per year in 1977, with a projected decrease by 1982 to about 6.2 megatons per year. This decrease is due to the progressively greater stringency of PART emission control standards at both the local and federal regulatory levels.

(Continued on page 9-25)

Table 9-1. DEFINITION OF MINERAL PRODUCTS PROCESSES

MSCC	Source Category	Charge Rate Unit
305002000	Asphaltic Concrete	
305002010	Rotary dryer	Tons produced
305002020	Other sources	Tons produced
305003000	Brick Manufacturing	
305003010	Drying	Tons produced
305003020	Grinding	Tons produced
305003030	Storage	Tons produced
305003990	Miscellaneous processes	Tons produced
305005000	Castable Refractory	
305005990	Other (not classified)	Tons feed material
305006000	Cement Manufacturing, Dry Process	
305006010	Kilns, total	Tons cement produced
305006020	Dryers, grinder, etc.	Tons cement produced
305006030	Kilns, oil-fired	Tons cement produced
305006040	Kilns, gas-fired	Tons cement produced
305006050	Kilns, coal-fired	Tons cement produced
305006990	Miscellaneous processes	Tons cement produced

Table 9-1. DEFINITION OF MINERAL PRODUCTS PROCESSES (Continued)

MSCC	Source Category	Charge Rate Unit
305007000	Cement Manufacturing, Wet Process	
305007010	Kilns, total	Tons cement produced
305007020	Dryers, grinder, etc.	Tons cement produced
305007030	Kilns, oil-fired	Tons cement produced
305007040	Kilns, gas-fired	Tons cement produced
305007050	Kilns, coal-fired	Tons cement produced
305007990	Miscellaneous processes	Tons cement produced
305008000	Ceramic Clay Manufacturing	
305008010	Drying	Tons input to process
305008020	Grinding	Tons input to process
305008030	Storage	Tons input to process
305008990	Miscellaneous processes	Tons input to process
305009000	Clay/Fly Ash Sintering	
305009030	Natural clay	Tons product

Table 9-1. DEFINITION OF MINERAL PRODUCTS PROCESSES (Continued)

MSCC	Source Category	Charge Rate Unit
305010000	Coal Cleaning	
305010010	Thermal drying, fluidized bed	Tons coal-dried
305010020	Thermal drying, flash	Tons coal-dried
305010030	Thermal drying, multilouvered	Tons coal-dried
305010990	Miscellaneous processes	Tons coal-dried
305014000	Glass Manufacturing	
305014010	Soda lime	Tons glass produced
305015000	Gypsum Manufacturing	
305015010	Dryer, raw material	Tons calcined gypsum produced
305015020	Primary grinder	Tons calcined gypsum produced
305015030	Calciner	Tons calcined gypsum produced
305015040	Conveying	Tons calcined gypsum produced
305015990	Miscellaneous processes	Tons calcined gypsum produced

Table 9-1. DEFINITION OF MINERAL PRODUCTS PROCESSES (Continued)

MSCC	Source Category	Charge Rate Unit
305016000	Lime Manufacturing	
305016010	Primary crushing	Tons lime produced
305016020	Secondary crushing	Tons lime produced
305016030	Calcining, vertical kiln	Tons lime produced
305016040	Calcining, rotary kiln	Tons lime produced
305016990	Miscellaneous processes	Tons lime produced
305018000	Perlite Manufacturing	
305018990	Miscellaneous Processes	Tons processed
305020000	Stone Quarrying/Processing	
305020010	Primary crushing	Tons raw material to primary crusher
305020020	Secondary crushing	Tons raw material to primary crusher
305020030	Tertiary crushing/screening	Tons raw material to primary crusher
305020040	Recrushing screening	Tons raw material to primary crusher

(Continued)

Table 9-1. DEFINITION OF MINERAL PRODUCTS PROCESSES (Continued)

MSCC	Source Category	Charge Rate Unit
305020000 (Continued)	Stone Quarrying/Processing	
305020050	Fines mill	Tons raw material to primary crusher
305020060	Screening/conveying/handling	Tons raw material to primary crusher
305020070	Open storage	Tons raw material to primary crusher
305020080	Cut stone, general	Tons processed
305020090	Blasting, general	Tons processed
305020990	Miscellaneous processes	Tons processed
305022000	Potash Production	
305022990	Miscellaneous processes	Tons processed
305024000	Mercury Carbonate	
305024010	Mining/processing	Tons product

Table 9-1. DEFINITION OF MINERAL PRODUCTS PROCESSES (Continued)

MSCC	Source Category	Charge Rate Unit
305025000	Sand and Gravel	
305025010	Crushing/screening	Tons product
305025991	Miscellaneous processes	Tons processed
305025992	Open storage	Tons product
305999990	Miscellaneous Processes	Tons processed

Table 9-2-a. 1977 MINERAL PRODUCTS EMISSIONS AND CHARGE RATES

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                         INDUSTRIAL PROCESS, MINERAL PRODUCTS                 PAGE  1
ANNUAL CHARGE RATES AND EMISSIONS PROJECTED TO 1977      RUN DATE= NOV 16,1977
 MODIFIED         TACRF                    EMISSIONS (MILLIONS OF TONS / YEAR)
   SCC         (SCC UNITS)           NOX            HC             CO           PART

305002000                            .046           .001           .004          .634

305002010     236670000.             .042           .001           .004          .493
305002020     236670000.             .003           NEG            NEG           .141

305003000                            NEG            NEG            NEG           .459

305003010      22600000.             NEG            NEG            NEG           .170
305003020      22600000.             NEG            NEG            NEG           .185
305003030      22600000.             NEG            NEG            NEG           .083
305003990      23414000.             NEG            NEG            NEG           .021

305005000                            NEG            NEG            NEG           .003

305005990       1165600.             NEG            NEG            NEG           .003

305006000                            .061           NEG            NEG           .601

305006010      33154000.             .037           NEG            NEG           .421
305006020      33154000.             .000           NEG            NEG           .164
305006990      78904000.             .024           NEG            NEG           .016

305007000                            .051           NEG            NEG           .548

305007010      39828000.             .051           NEG            NEG           .471
305007020      40623000.             NEG            NEG            NEG           .067
305007990      27902000.             .000           NEG            NEG           .011

305008000                            .003           NEG            .001          .182

305008010      10658000.             .002           NEG            NEG           .074
305008020      10658000.             NEG            NEG            .001          .068
305008030      10658000.             NEG            NEG            NEG           .033
305008990      20700000.             .001           NEG            NEG           .006

305009000                            NEG            NEG            NEG           .020

305009030       3372700.             NEG            NEG            NEG           .020
```

Table 9-2-a. 1977 MINERAL PRODUCTS EMISSIONS AND CHARGE RATES (Continued)

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                          INDUSTRIAL PROCESS, MINERAL PRODUCTS                 PAGE  2
ANNUAL CHARGE RATES AND EMISSIONS PROJECTED TO 1977    RUN DATE= NOV 16,1977
  MODIFIED        TACRF                  EMISSIONS (MILLIONS OF TONS / YEAR)
    SCC        (SCC UNITS)         NOX           HC            CO           PART
 305010000
                                   .006          NEG           .001          .097
 305010010      48858000.          NEG           NEG           NEG           .058
 305010020      19178000.          NEG           NEG           NEG           .018
 305010030      12036000.          NEG           NEG           NEG           .018
 305010990      80072000.          .006          NEG           .001          .002
 305014000
                                   .019          NEG           NEG           .013
 305014010      15423000.          .019          NEG           NEG           .013
 305015000
                                   .002          NEG           NEG           .081
 305015010      10820000.          NEG           NEG           NEG           .024
 305015020      10820000.          NEG           NEG           NEG           .001
 305015030      10820000.          .001          NEG           NEG           .054
 305015040      10820000.          NEG           NEG           NEG           .000
 305015990      21640000.          .002          NEG           NEG           .002
 305016000
                                   .003          .000          .002          .388
 305016010      20646000.          NEG           NEG           NEG           .004
 305016020      20646000.          NEG           NEG           NEG           .011
 305016030       2064600.          .000          .000          .002          .003
 305016040      18602000.          .002          NEG           NEG           .353
 305016990      20646000.          .001          NEG           NEG           .018
 305018000
                                   NEG           NEG           NEG           .002
 305018990       2616600.          NEG           NEG           NEG           .002
 305020000
                                   .053          .002          .014         3.793
 305020010     924220000.          NEG           NEG           NEG           .107
 305020020     924220000.          NEG           NEG           NEG           .321
 305020030     965500000.          NEG           NEG           NEG          1.011
 305020040     965500000.          NEG           NEG           NEG           .168
 305020050     965500000.          NEG           NEG           NEG          1.011
```

Table 9-2-a. 1977 MINERAL PRODUCTS EMISSIONS AND CHARGE RATES (Continued)

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                         INDUSTRIAL PROCESS, MINERAL PRODUCTS                    PAGE  3
ANNUAL CHARGE RATES AND EMISSIONS PROJECTED TO 1977     RUN DATE= NOV 16,1977
 MODIFIED           TACRF
   SCC          (SCC UNITS)               EMISSIONS (MILLIONS OF TONS / YEAR)
                                   NOX           HC            CO            PART

305020060       965500000.         NEG           NEG           NEG           .400
305020070       965500000.         .009          NEG           NEG           .291
305020080        21636000.         NEG           NEG           NEG           .096
305020090        48324000.         NEG           NEG           NEG           .163
305020990       148360000.         .044          .002          .014          .224

305022000                          NEG           NEG           NEG           .048

305022990         2296300.         NEG           NEG           NEG           .048

305024000                          NEG           NEG           NEG           .009

305024010          5029000.        NEG           NEG           NEG           .009

305025000                          .032          NEG           .010          .596

305025010       861360000.         NEG           NEG           NEG           .118
305025990      1390000000.         .032          NEG           .010          .477

305025991       528600000.         .032          NEG           .010          .218
305025992       861360000.         NEG           NEG           NEG           .260

305999000                          .018          .011          .024          .239

305999990        88927000.         .018          .011          .024          .239
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Table 9-2-b. 1977 MINERAL PRODUCTS UNCERTAINTIES

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                           INDUSTRIAL PROCESS, MINERAL PRODUCTS                     PAGE  1
TACR AND EMISSION UNCERTAINTIES PROJECTED TO 1977          RUN DATE= NOV 16,1977
MODIFIED          TACRF                  EMISSIONS (MILLIONS OF TONS / YEAR)
  SCC          (SCC UNITS)         NOX              HC              CO              PART
305002000
                                 +  .009        +  .000        +  .001        +  .241
                                 -  .009        -  .000        -  .001        -  .294
305002010     +   7016600.       +  .009        +  .000        +  .001        +  .232
              -   7016600.       -  .009        -  .000        -  .001        -  .283
305002020     +   7016600.       +  .001           NEG            NEG         +  .066
              -   7016600.       -  .001           NEG            NEG         -  .081
305003000
                                    NEG            NEG            NEG         +  .090
                                    NEG            NEG            NEG         -  .098
305003010     +    680660.          NEG            NEG            NEG         +  .058
              -    680660.          NEG            NEG            NEG         -  .063
305003020     +    680660.          NEG            NEG            NEG         +  .063
              -    680660.          NEG            NEG            NEG         -  .068
305003030     +    680660.          NEG            NEG            NEG         +  .028
              -    680660.          NEG            NEG            NEG         -  .031
305003990     +    701050.          NEG            NEG            NEG         +  .008
              -    701050.          NEG            NEG            NEG         -  .009
305005000
                                    NEG            NEG            NEG         +  .001
                                    NEG            NEG            NEG         -  .001
305005990     +     57764.          NEG            NEG            NEG         +  .001
              -     57764.          NEG            NEG            NEG         -  .001
305006000
                                 +  .008           NEG            NEG         +  .257
                                 -  .008           NEG            NEG         -  .280
305006010     +   1188600.       +  .005           NEG            NEG         +  .244
              -   1188600.       -  .005           NEG            NEG         -  .265
305006020     +   1188600.       +  .000           NEG            NEG         +  .082
              -   1188600.       -  .000           NEG            NEG         -  .092
305006990     +  14907000.       +  .007           NEG            NEG         +  .009
              -  14907000.       -  .007           NEG            NEG         -  .010
305007000
                                 +  .006           NEG            NEG         +  .275
                                 -  .011           NEG            NEG         -  .298
```

Table 9-2-b. 1977 MINERAL PRODUCTS UNCERTAINTIES (Continued)

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                    INDUSTRIAL PROCESS, MINERAL PRODUCTS                    PAGE  2
TACR AND EMISSION UNCERTAINTIES PROJECTED TO 1977        RUN DATE= NOV 16,1977
 MODIFIED          TACR                  EMISSIONS (MILLIONS OF TONS / YEAR)
   SCC          (SCC UNITS)        NOX            HC            CO           PART

305007010   +    1003600.      +  .006           NEG           NEG        +  .272
            -    1003600.      -  .011           NEG           NEG        -  .296
305007020   +    1023700.          NEG           NEG           NEG        +  .034
            -    1023700.          NEG           NEG           NEG        -  .038
305007990   +    5620400.      +  .000           NEG           NEG        +  .006
            -    5620400.      -  .000           NEG           NEG        -  .007

305008000                      +  .000           NEG       +  .000        +  .037
                               -  .000           NEG       -  .000        -  .040

305008010   +     731820.      +  .000           NEG           NEG        +  .026
            -     731820.      -  .000           NEG           NEG        -  .028
305008020   +     731820.          NEG           NEG       +  .000        +  .024
            -     731820.          NEG           NEG       -  .000        -  .026
305008030   +     731820.          NEG           NEG           NEG        +  .011
            -     731820.          NEG           NEG           NEG        -  .012
305008990   +    1423500.      +  .000           NEG           NEG        +  .002
            -    1423500.      -  .000           NEG           NEG        -  .003

305009000                          NEG           NEG           NEG        +  .004
                                   NEG           NEG           NEG        -  .004

305009030   +     311220.          NEG           NEG           NEG        +  .004
            -     311220.          NEG           NEG           NEG        -  .004

305010000                      +  .001           NEG       +  .000        +  .024
                               -  .001           NEG       -  .000        -  .033

305010010   +    2397700.          NEG           NEG           NEG        +  .022
            -    2397700.          NEG           NEG           NEG        -  .030
305010020   +     944020.          NEG           NEG           NEG        +  .007
            -     944020.          NEG           NEG           NEG        -  .009
305010030   +     589860.          NEG           NEG           NEG        +  .007
            -     589860.          NEG           NEG           NEG        -  .009
305010990   +    3932600.      +  .001           NEG       +  .000        +  .001
            -    3932600.      -  .001           NEG       -  .000        -  .001
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Table 9-2-b. 1977 MINERAL PRODUCTS UNCERTAINTIES (Continued)

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                     INDUSTRIAL PROCESS, MINERAL PRODUCTS                 PAGE  3
TACR AND EMISSION UNCERTAINTIES PROJECTED TO 1977        RUN DATE= NOV 16,1977
 MODIFIED          TACRP                  EMISSIONS (MILLIONS OF TONS / YEAR)
   SCC          (SCC UNITS)           NOX             HC            CO            PART

305014000                          + .005            NEG           NEG         + .002
                                   - .005            NEG           NEG         - .002

305014010    +     1548500.        + .005            NEG           NEG         + .002
             -     1548500.        - .005            NEG           NEG         - .002

305015000                          + .036            NEG           NEG         + .028
                                   - .001            NEG           NEG         - .033

305015010    +      219540.          NEG             NEG           NEG         + .012
             -      219540.          NEG             NEG           NEG         - .014
305015020    +      219540.          NEG             NEG           NEG         + .000
             -      219540.          NEG             NEG           NEG         - .000
305015030    +      219540.        + .000            NEG           NEG         + .026
             -      219540.        - .000            NEG           NEG         - .031
305015040    +      219540.          NEG             NEG           NEG         + .000
             -      219540.          NEG             NEG           NEG         - .000
305015990    +      439070.        + .036            NEG           NEG         + .001
             -      439070.        - .001            NEG           NEG         - .001

305016000                          + .000         + .000        + .000         + .180
                                   - .000         - .000        - .000         - .208

305016010    +      507960.          NEG             NEG           NEG         + .001
             -      507960.          NEG             NEG           NEG         - .001
305016020    +      507960.          NEG             NEG           NEG         + .003
             -      507960.          NEG             NEG           NEG         - .003
305016030    +      100400.        + .000         + .000        + .000         + .001
             -      100400.        - .000         - .000        - .000         - .001
305016040    +      457200.        + .000            NEG           NEG         + .180
             -      457200.        - .000            NEG           NEG         - .208
305016990    +      507960.        + .000            NEG           NEG         + .006
             -      507960.        - .000            NEG           NEG         - .006

305018000                            NEG             NEG           NEG         + .001
                                     NEG             NEG           NEG         - .001
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Table 9-2-b. 1977 MINERAL PRODUCTS UNCERTAINTIES (Continued)

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                    INDUSTRIAL PROCESS, MINERAL PRODUCTS                  PAGE  4
TACF AND EMISSION UNCERTAINTIES PROJECTED TO 1977       RUN DATE= NOV 16,1977
 MODIFIED         TACRF                EMISSIONS (MILLIONS OF TONS / YEAR)
   SCC        (SCC UNITS)            NOX          HC           CO          PART

305018990  +     130930.              NEG          NEG          NEG       +  .001
           -     130930.              NEG          NEG          NEG       -  .001

305020000                        +  .012      +  .001      +  .004       +  .864
                                 -  .012      -  .001      -  .004       -  .872

305020010  +   27457000.              NEG          NEG          NEG       +  .026
           -   27457000.              NEG          NEG          NEG       -  .026
305020020  +   27457000.              NEG          NEG          NEG       +  .078
           -   27457000.              NEG          NEG          NEG       -  .078
305020030  +   19544000.              NEG          NEG          NEG       +  .595
           -   19544000.              NEG          NEG          NEG       -  .601
305020040  +   19544000.              NEG          NEG          NEG       +  .055
           -   19544000.              NEG          NEG          NEG       -  .057
305020050  +   19544000.              NEG          NEG          NEG       +  .595
           -   19544000.              NEG          NEG          NEG       -  .601
305020060  +   19544000.              NEG          NEG          NEG       +  .110
           -   19544000.              NEG          NEG          NEG       -  .110
305020070  +   19544000.         +  .002          NEG          NEG       +  .087
           -   19544000.         -  .002          NEG          NEG       -  .087
305020080  +    2104200.              NEG          NEG          NEG       +  .027
           -    2104200.              NEG          NEG          NEG       -  .027
305020090  +    9404700.              NEG          NEG          NEG       +  .048
           -    9404700.              NEG          NEG          NEG       -  .046
305020990  +   28815000.         +  .012      +  .001      +  .004       +  .075
           -   28815000.         -  .012      -  .001      -  .004       -  .075

305022000                             NEG          NEG          NEG       +  .016
                                      NEG          NEG          NEG       -  .016

305022990  +    1157400.              NEG          NEG          NEG       +  .016
           -    1157400.              NEG          NEG          NEG       -  .016

305024000                             NEG          NEG          NEG       +  .002
                                      NEG          NEG          NEG       -  .002

305024010  +     256420.              NEG          NEG          NEG       +  .002
           -     256420.              NEG          NEG          NEG       -  .002
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Table 9-2-b. 1977 MINERAL PRODUCTS UNCERTAINTIES (Continued)

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                    INDUSTRIAL PROCESS, MINERAL PRODUCTS                   PAGE  5
TACR AND EMISSION UNCERTAINTIES PROJECTED TO 1977      RUN DATE= NOV 16,1977
 MODIFIED         TACRP            EMISSIONS (MILLIONS OF TONS / YEAR)
  SCC         (SCC UNITS)       NOX           HC           CO          PART

305025000                     + .007          NEG      + .002      + .163
                              - .007          NEG      - .002      - .163

305025010   +   17453000.       NEG           NEG        NEG       + .102
            -   17453000.       NEG           NEG        NEG       - .102
305025990   +   20503000.     + .007          NEG      + .002      + .127
            -   20503000.     - .007          NEG      - .002      - .127

305025991   +   10760000.     + .007          NEG      + .002      + .100
            -   10760000.     - .007          NEG      - .002      - .100
305025992   +   17453000.       NEG           NEG        NEG       + .078
            -   17453000.       NEG           NEG        NEG       - .078

305999000                     + .005     + .003        + .006      + .063
                              - .005     - .003        - .006      - .063

305999990   +    4490600.     + .005     + .003        + .006      + .063
            -    4490600.     - .005     - .003        - .006      - .063
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Table 9-3-a. 1982 MINERAL PRODUCTS EMISSIONS AND CHARGE RATES

INDUSTRIAL PROCESS, MINERAL PRODUCTS PAGE 1

ANNUAL CHARGE RATES AND EMISSIONS PROJECTED TO 1982 RUN DATE= NOV 16,1977

MODIFIED SCC	TACRP (SCC UNITS)	EMISSIONS (MILLIONS OF TONS / YEAR) NOX	HC	CO	PART
305002000		.044	.001	.003	.500
305002010	280020000.	.041	.001	.003	.389
305002020	280020000.	.003	NEG	NEG	.111
305003000		NEG	NEG	NEG	.382
305003010	25100000.	NEG	NEG	NEG	.142
305003020	25100000.	NEG	NEG	NEG	.154
305003030	25100000.	NEG	NEG	NEG	.069
305003990	25999000.	NEG	NEG	NEG	.018
305005000		NEG	NEG	NEG	.002
305005990	1326600.	NEG	NEG	NEG	.002
305006000		.078	NEG	NEG	.438
305006010	46554000.	.047	NEG	NEG	.307
305006020	46554000.	.000	NEG	NEG	.119
305006990	110800000.	.030	NEG	NEG	.012
305007000		.045	NEG	NEG	.272
305007010	38068000.	.045	NEG	NEG	.234
305007020	38828000.	NEG	NEG	NEG	.033
305007990	26667000.	.000	NEG	NEG	.005
305008000		.003	NEG	.001	.157
305008010	12268000.	.002	NEG	NEG	.064
305008020	12268000.	NEG	NEG	.001	.059
305008030	12268000.	NEG	NEG	NEG	.029
305008990	23825000.	.001	NEG	NEG	.005
305009000		NEG	NEG	NEG	.014
305009030	3831200.	NEG	NEG	NEG	.014

Table 9-3-a. 1982 MINERAL PRODUCTS EMISSIONS AND CHARGE RATES (Continued)

INDUSTRIAL PROCESS, MINERAL PRODUCTS PAGE 2

ANNUAL CHARGE RATES AND EMISSIONS PROJECTED TO 1982 RUN DATE= NOV 16,1977

MODIFIED SCC	TACRF (SCC UNITS)	EMISSIONS (MILLIONS OF TONS / YEAR) NOX	HC	CO	PART
305010000		.005	NEG	.000	.068
305010010	51253000.	NEG	NEG	NEG	.041
305010020	20123000.	NEG	NEG	NEG	.013
305010030	12626000.	NEG	NEG	NEG	.013
305010990	84002000.	.005	NEG	.000	.002
305014000		.020	NEG	NEG	.011
305014010	17513000.	.020	NEG	NEG	.011
305015000		.002	NEG	NEG	.068
305015010	12820000.	NEG	NEG	NEG	.020
305015020	12820000.	NEG	NEG	NEG	.001
305015030	12820000.	.001	NEG	NEG	.046
305015040	12820000.	NEG	NEG	NEG	.000
305015990	25640000.	.001	NEG	NEG	.002
305016000		.004	.000	.002	.307
305016010	23436000.	NEG	NEG	NEG	.002
305016020	23436000.	NEG	NEG	NEG	.007
305016030	2343600.	.001	.000	.002	.002
305016040	21112000.	.002	NEG	NEG	.285
305016990	23436000.	.001	NEG	NEG	.011
305018000		NEG	NEG	NEG	.001
305018990	2971600.	NEG	NEG	NEG	.001
305020000		.058	.002	.012	3.337
305020010	1096200000.	NEG	NEG	NEG	.089
305020020	1096200000.	NEG	NEG	NEG	.267
305020030	1143000000.	NEG	NEG	NEG	.822
305020040	1143000000.	NEG	NEG	NEG	.137
305020050	1143000000.	NEG	NEG	NEG	.822

Table 9-3-a. 1982 MINERAL PRODUCTS EMISSIONS AND CHARGE RATES (Continued)

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                    INDUSTRIAL PROCESS, MINERAL PRODUCTS                      PAGE  3
ANNUAL CHARGE RATES AND EMISSIONS PROJECTED TO 1982    RUN DATE= NOV 16,1977
 MODIFIED        TACRF                     EMISSIONS (MILLIONS OF TONS / YEAR)
   SCC        (SCC UNITS)           NOX            HC            CO          PART

305020060     1143000000.           NEG           NEG           NEG          .354
305020070     1143000000.          .010           NEG           NEG          .340
305020080       25611000.           NEG           NEG           NEG          .094
305020090       57224000.           NEG           NEG           NEG          .190
305020990      175610000.          .048          .002          .012          .221

305022000                           NEG           NEG           NEG          .040

305022990       26093000.           NEG           NEG           NEG          .040

305024000                           NEG           NEG           NEG          .008

305024010        5704000.           NEG           NEG           NEG          .008

305025000                          .031           NEG          .008          .604

305025010     1019900000.           NEG           NEG           NEG          .106
305025990     1646000000.          .031           NEG          .008          .498

305025991      626100000.          .031           NEG          .008          .195
305025992     1019900000.           NEG           NEG           NEG          .303


305999000                          .017          .009          .023          .187

305999990      100980000.          .017          .009          .023          .187
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Table 9-3-b. 1982 MINERAL PRODUCTS UNCERTAINTIES

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                        INDUSTRIAL PROCESS, MINERAL PRODUCTS                         PAGE  1
TACR AND EMISSION UNCERTAINTIES PROJECTED TO 1982           RUN DATE= NOV 16,1977
 MODIFIED          TACRP               EMISSIONS (MILLIONS OF TONS / YEAR)
   SCC          (SCC UNITS)        NOX           HC             CO             PART
305002000
                                 + .011        + .000         + .001         + .359
                                 - .011        - .000         - .000         - .404
305002010     +   12409000.      + .011        + .000         + .001         + .345
              -   12409000.      - .011        - .000         - .000         - .389
305002020     +   12409000.      + .001          NEG            NEG          + .099
              -   12409000.      - .000          NEG            NEG          - .111
305003000
                                   NEG           NEG            NEG          + .116
                                   NEG           NEG            NEG          - .145
305003010     +    1098100.        NEG           NEG            NEG          + .074
              -    1098100.        NEG           NEG            NEG          - .093
305003020     +    1098100.        NEG           NEG            NEG          + .081
              -    1098100.        NEG           NEG            NEG          - .101
305003030     +    1098100.        NEG           NEG            NEG          + .036
              -    1098100.        NEG           NEG            NEG          - .045
305003990     +    1133300.        NEG           NEG            NEG          + .010
              -    1133300.        NEG           NEG            NEG          - .012
305005000
                                   NEG           NEG            NEG          + .001
                                   NEG           NEG            NEG          - .001
305005990     +      77455.        NEG           NEG            NEG          + .001
              -      77455.        NEG           NEG            NEG          - .001
305006000
                                 + .012          NEG            NEG          + .322
                                 - .012          NEG            NEG          - .330
305006010     +    4763500.      + .008          NEG            NEG          + .301
              -    4763500.      - .008          NEG            NEG          - .307
305006020     +    4763500.      + .000          NEG            NEG          + .113
              -    4763500.      - .000          NEG            NEG          - .119
305006990     +   19655000.      + .009          NEG            NEG          + .012
              -   19655000.      - .009          NEG            NEG          - .012
305007000
                                 + .010          NEG            NEG          + .230
                                 - .007          NEG            NEG          - .236
```

Table 9-3-b. 1982 MINERAL PRODUCTS UNCERTAINTIES (Continued)

```
                          INDUSTRIAL PROCESS, MINERAL PRODUCTS                         PAGE  2
TACR AND EMISSION UNCERTAINTIES PROJECTED TO 1982          RUN DATE= NOV 16,1977
 MODIFIED        TACRF                 EMISSIONS (MILLIONS OF TONS / YEAR)
   SCC        (SCC UNITS)          NOX             HC             CO             PART
305007010   +   1173900.      +  .010            NEG            NEG          +  .228
            -   1173900.      -  .007            NEG            NEG          -  .234
305007020   +   1197000.          NEG            NEG            NEG          +  .031
            -   1197000.          NEG            NEG            NEG          -  .033
305007990   +   5642200.      +  .000            NEG            NEG          +  .005
            -   5642200.      -  .000            NEG            NEG          -  .005
305008000                     +  .000            NEG        +  .000          +  .048
                              -  .000            NEG        -  .000          -  .061
305008010   +    820270.      +  .000            NEG            NEG          +  .034
            -    820270.      -  .020            NEG            NEG          -  .042
305008020   +    820270.          NEG            NEG        +  .000          +  .031
            -    820270.          NEG            NEG        -  .000          -  .039
305008030   +    820270.          NEG            NEG            NEG          +  .015
            -    820270.          NEG            NEG            NEG          -  .019
305008990   +   1594400.      +  .000            NEG            NEG          +  .003
            -   1594400.      -  .000            NEG            NEG          -  .004
305009000                         NEG            NEG            NEG          +  .005
                                  NEG            NEG            NEG          -  .005
305009030   +    347210.          NEG            NEG            NEG          +  .005
            -    347210.          NEG            NEG            NEG          -  .005
305010000                     +  .001            NEG        +  .000          +  .028
                              -  .001            NEG        -  .000          -  .041
305010010   +   2482300.          NEG            NEG            NEG          +  .026
            -   2482300.          NEG            NEG            NEG          -  .038
305010020   +    977300.          NEG            NEG            NEG          +  .008
            -    977300.          NEG            NEG            NEG          -  .012
305010030   +    610390.          NEG            NEG            NEG          +  .008
            -    610390.          NEG            NEG            NEG          -  .012
305010990   +   4071100.      +  .001            NEG        +  .000          +  .001
            -   4071100.      -  .001            NEG        -  .000          -  .002
```

Table 9-3-b. 1982 MINERAL PRODUCTS UNCERTAINTIES (Continued)

```
                     INDUSTRIAL PROCESS, MINERAL PRODUCTS                  PAGE  3
TACR AND EMISSION UNCERTAINTIES PROJECTED TO 1982       RUN DATE= NOV 16,1977
 MODIFIED          TACRF                 EMISSIONS (MILLIONS OF TONS / YEAR)
   SCC          (SCC UNITS)         NOX            HC            CO            PART
305014000                        + .006           NEG           NEG        +  .003
                                 - .006           NEG           NEG        -  .003

305014010     +    1701200.      + .006           NEG           NEG        +  .003
              -    1701200.      - .006           NEG           NEG        -  .003

305015000                        + .042           NEG           NEG        +  .041
                                 - .000           NEG           NEG        -  .050

305015010     +     509310.        NEG            NEG           NEG        +  .017
              -     509310.        NEG            NEG           NEG        -  .020
305015020     +     509310.        NEG            NEG           NEG        +  .000
              -     509310.        NEG            NEG           NEG        -  .001
305015030     +     509310.      + .000           NEG           NEG        +  .037
              -     509310.      - .000           NEG           NEG        -  .046
305015040     +     509310.        NEG            NEG           NEG        +  .000
              -     509310.        NEG            NEG           NEG        -  .000
305015990     +    1018600.      + .042           NEG           NEG        +  .001
              -    1018600.      - .000           NEG           NEG        -  .002

305016000                        + .001      + .000        + .001          +  .237
                                 - .000      - .000        - .001          -  .285

305016010     +     819740.        NEG            NEG           NEG        +  .002
              -     819740.        NEG            NEG           NEG        -  .002
305016020     +     819740.        NEG            NEG           NEG        +  .005
              -     819740.        NEG            NEG           NEG        -  .005
305016030     +     119250.      + .000      + .000        + .001          +  .001
              -     119250.      - .000      - .000        - .001          -  .001
305016040     +     738690.      + .001           NEG           NEG        +  .237
              -     738690.      - .000           NEG           NEG        -  .285
305016990     +     819740.      + .000           NEG           NEG        +  .008
              -     819740.      - .000           NEG           NEG        -  .009

305018000                          NEG            NEG           NEG        +  .001
                                   NEG            NEG           NEG        -  .001
```

Table 9-3-b. 1982 MINERAL PRODUCTS UNCERTAINTIES (Continued)

```
                         INDUSTRIAL PROCESS, MINERAL PRODUCTS                                   PAGE  4
 TACR AND EMISSION UNCERTAINTIES PROJECTED TO 1982        RUN DATE= NOV 16,1977
  MODIFIED         TACRF                     EMISSIONS (MILLIONS OF TONS / YEAR)
    SCC         (SCC UNITS)           NOX                HC                 CO             PART
 305018990   +     176240.            NEG                NEG                NEG          +  .001
             -     176240.            NEG                NEG                NEG          -  .001
 305020000                         +  .014            +  .001            +  .007         +  .828
                                   -  .010            -  .001            -  .004         -  .910
 305020010   +   48124000.            NEG                NEG                NEG          +  .035
             -   48124000.            NEG                NEG                NEG          -  .036
 305020020   +   48124000.            NEG                NEG                NEG          +  .104
             -   48124000.            NEG                NEG                NEG          -  .107
 305020030   +   45227000.            NEG                NEG                NEG          +  .561
             -   45227000.            NEG                NEG                NEG          -  .618
 305020040   +   45227000.            NEG                NEG                NEG          +  .065
             -   45227000.            NEG                NEG                NEG          -  .078
 305020050   +   45227000.            NEG                NEG                NEG          +  .561
             -   45227000.            NEG                NEG                NEG          -  .618
 305020060   +   45227000.            NEG                NEG                NEG          +  .137
             -   45227000.            NEG                NEG                NEG          -  .151
 305020070   +   45227000.         +  .002               NEG                NEG          +  .103
             -   45227000.         -  .002               NEG                NEG          -  .103
 305020080   +    2312600.            NEG                NEG                NEG          +  .031
             -    2312600.            NEG                NEG                NEG          -  .032
 305020090   +    9641900.            NEG                NEG                NEG          +  .053
             -    9641900.            NEG                NEG                NEG          -  .051
 305020990   +   29557000.         +  .014            +  .001            +  .007         +  .083
             -   29557000.         -  .010            -  .001            -  .004         -  .083
 305022000                            NEG                NEG                NEG          +  .018
                                      NEG                NEG                NEG          -  .020
 305022990   +    1564200.            NEG                NEG                NEG          +  .018
             -    1564200.            NEG                NEG                NEG          -  .020
 305024000                            NEG                NEG                NEG          +  .002
                                      NEG                NEG                NEG          -  .002
 305024010   +     347020.            NEG                NEG                NEG          +  .002
             -     347020.            NEG                NEG                NEG          -  .002
```

Table 9-3-b. 1982 MINERAL PRODUCTS UNCERTAINTIES (Continued)

INDUSTRIAL PROCESS, MINERAL PRODUCTS PAGE 5

TACR AND EMISSION UNCERTAINTIES PROJECTED TO 1982 RUN DATE= NOV 16,1977

MODIFIED SCC	TACRF (SCC UNITS)	EMISSIONS (MILLIONS OF TONS / YEAR) NOX	HC	CO	PART
305025000		+ .009	NEG	+ .003	+ .179
		- .009	NEG	- .002	- .179
305025010	+ 40387000.	NEG	NEG	NEG	+ .100
	- 40387000.	NEG	NEG	NEG	- .100
305025990	+ 47394000.	+ .009	NEG	+ .003	+ .149
	- 47394000.	- .009	NEG	- .002	- .149
305025991	+ 24802000.	+ .009	NEG	+ .003	+ .117
	- 24802000.	- .009	NEG	- .002	- .117
305025992	+ 40387000.	NEG	NEG	NEG	+ .092
	- 40387000.	NEG	NEG	NEG	- .092
305999000		+ .007	+ .004	+ .007	+ .072
		- .005	- .004	- .007	- .072
305999990	+ 6068200.	+ .007	+ .004	+ .007	+ .072
	- 6068200.	- .005	- .004	- .007	- .072

Those industries which are the main sources of PART emissions are listed in Table 9-4 in the order of decreasing PART emissions rate for 1977. The projected level of PART emissions for 1982 are included for comparison. Table 9-4 shows that the major contributor to PART emissions is the stone quarrying and processing industry, which accounts for approximately half of the total PART emissions shown for all mineral products industries. PART emissions are high in this category for several reasons: (1) the high PART emissions factor; (2) the large process tonnage involved; and (3) the somewhat low level of PART emissions control in relation to most of the other mineral products categories. The numerical value of the uncontrolled emission factors for stone processing is, however, more questionable than for some of the other mineral product categories. The significance of each of these factors is treated in Section 9.4.

Other major sources of particulate emissions are cement manufacturing (both wet and dry processes), sand and gravel processing, asphaltic concrete production, brick and clay manufacturing (combined in Table 9-4 due to the basic similarity of the unit operations involved), and lime manufacturing. Sand and gravel processing is the only industry category showing a projected increase in PART emissions between 1977 and 1982. This results from the projected increase in process rate plus the assumption that one of the major emission sources (open storage) will be subjected to little additional control by 1982. Details on this and other factors underlying the above data are discussed in Section 9.4.

NO_x emissions for all mineral products industries are relatively low, about 0.29 megatons per year in 1977, with about 0.31 megatons per year projected for 1982. HC and CO emissions are not significant.

9.3 APPROACH

This section describes the basic approach used to gather and analyze the data upon which the emission inventory data shown in the preceding subsection were based. Data acquisition and interpretation focused on three main areas: (1) charge rate information (present and

Table 9-4. PARTICULATE EMISSIONS

MSCC		1977		1982	
305-xxx-000	Source Category	10^6 tons/yr	% of Total	10^6 tons/yr	% of Total
020	Stone processing	3.834	49.32	3.337	53.43
006+007	Cement	1.125	14.47	0.710	11.37
002	Asphaltic concrete	0.652	8.39	0.500	8.01
003+008	Brick and clay	0.645	8.30		
025	Sand and gravel	0.589	7.58	0.604	9.67
016	Lime	0.400	5.15	0.307	4.92
010	Coal cleaning	0.102	1.31	0.068	1.09
015	Gypsum	0.083	1.07	0.068	1.09
Subtotal		7.430	95.59	5.982	95.79
999	Miscellaneous	0.247	3.18	0.187	2.99
Totals		7.677	98.76	6.169	98.78

projected levels); (2) uncontrolled emission factors; and (3) present and projected levels of technology and application of PART control equipment.

The primary data sources for charge rate information were three series of publications by the Bureau of Mines, U. S. Department of the Interior. These were the Minerals Yearbook (past annual issues and the most recent preprints of selected chapters), Mineral Industry Surveys (monthly, annual advance summaries and preliminary summaries by industry), and Mineral Facts and Problems, 1975 edition. These sources provided a complete and internally consistent set of statistics for historical, current, and projected production and/or process rates for most of the process categories of interest. Useful sources of supporting information were current and back issues of Rock Products magazine and Pit and Quarry magazine (both published in Chicago, Illinois). Trade associations such as the Portland Cement Association and the National Asphalt Pavement Association also provided useful information and statistics on production rates and projected growth rates.

The main source for uncontrolled emission factors was the EPA compilation of Air Pollutant Emission Factors, AP-42 (Ref. 9-1). Cognizant EPA personnel at Durham, North Carolina, were contacted to ensure that the most recent information was used for each process category.

The most difficult aspect of data acquisition and analysis concerned the assessment of the PART control technology and the extent of application of that technology to each process category. All of the data sources mentioned were utilized for this purpose. EPA standards support documents were useful for those industries for which new source performance standards have been promulgated or proposed. Appendix IV-D of Ref. 9-2 provided helpful guidelines concerning the PART emission control standards in use by the different states. Reference 9-3, prepared by the Los Angeles Air Pollution Control District, provided detailed information on those process categories which are in operation in the Los Angeles area. A literature search of relevant technical journals, particularly Chemical Engineering, Journal of the Air Pollution Control

Association, and Environmental Science and Technology, also provided useful inputs. For each process category, a best judgment selection was made from all of the inputs from these sources of current and projected pollution control equipment efficiency and application.

The existing NEDS data base (Ref. 9-4) was examined for each process category in terms of each of the three main areas of data acquisition (charge rate, uncontrolled emission factors, and application and efficiency of control techniques). The NEDS charge rate data were, in general, substantially lower than the corresponding Bureau of Mines data. The NEDS charge rate data were only utilized for some of the -099 "other(not classified)" categories, which could not be reasonably assigned to identifiable processes or unit operations. Uncontrolled PART emission factors for these unidentified processes were derived from the NEDS data. The detailed printouts of the NEDS data which showed the generic type of control equipment in use, and its extent, were useful in that they permitted estimates to be made of PART emission control equipment application and the effectiveness for each process. This information formed a valid input to the final selection of present and projected values for these parameters. The NEDS data were also the main source of the relatively small uncontrolled emission factors for NO_x, HC, and CO. These parameters were, in general, not covered in Ref. 9-1.

9.4 DISCUSSION

The key aspect of the mineral products industrial classification, from the viewpoint of this study, is clearly PART emissions. This section is accordingly restricted to a discussion of the more important individual factors which are influential on the final computed value of particulate emissions summarized in Section 9.2.

The indicated emissions from the stone quarrying and processing industry (MSCC 305020000) are of overriding magnitude. It is important to note that the uncontrolled emission factors for the subcategories -010 thru -060 are based on PART emissions measurements performed on one occasion at one stone crushing plant (Refs. 9-5 and 9-6). Moreover, the emission factors for these subcategories were all expressed in terms of pounds of emissions per pound of rock input to the primary crusher. This forces one to make the assumption that the ratio of process rock to the other subcategories (such as tertiary crushing/screening, -030, and fines mill, -050) which prevailed during this test is representative of the industry-wide average. An error in this assumption could be highly significant because, as shown in Tables 9-2-a and 9-3-a, these two subcategories (-030 and -050) account for approximately half the indicated emissions for all of the stone processing industry (MSCC 305020000), which in turn accounts for approximately half of all indicated PART emissions for the entire mineral products industrial classification.

If the magnitude of the indicated PART emissions from the stone processing industry is judged to be of significant concern, it would appear that a necessary first course of action would be to expand the data base from which these uncontrolled emission factors were derived.

Another interesting subcategory of stone processing is -070, Open Storage. Reference 9-7 describes a careful series of measurements performed on a sand and gravel processing plant, the results of which have been incorporated by EPA (Ref. 9-1) into the AP-42 emission factors for stone processing. This emission factor is expressed as

$$E = \frac{0.33}{\left(\frac{PE}{100}\right)^2} \qquad (9\text{-}1)$$

where PE is a precipitation-evaporation index, numerical values of which are given by geographical location in AP-42. From the AP-42 geographical presentation, this study estimated an average value of PE for each state and applied the resulting emission factor to the charge rate of stone quarrying/processing for that state (as given in the Bureau of Mines Mineral Yearbook). Total PART emissions were then summed over all the states and divided by the national charge rate to yield a nationwide average estimate for the uncontrolled emission factor for open storage of 0.61

lb/ton of material stored. It was assumed that all crushed stone production is subject to open storage at some stage of its processing. It is interesting to note that the value of 0.61 lb/ton is approximately 16 times smaller than the former AP-42 value of 10 lb/ton, which was apparently based on an estimate, unsupported by measurement (Ref. 9-5).

The next largest source of PART emissions in the mineral products category is cement manufacturing (wet and dry processes combined). This was the first industry in the mineral products category to be subjected to EPA new source performance standards and, consequently, is expected to be in an advanced state of control by 1982. It should be noted that MSCC process categories 305006010 and 305007010 represent all kiln operations (for the dry and wet processes, respectively) for all types of fuel. NEDS further provides categories (-030, -040, and -050) corresponding to oil-, gas-, and coal-fired kilns, respectively, for both 305006000 and 305007000. AP-42 PART emission factors are identical for all these kiln operations, however, regardless of the fuel. That is, MSCC 305006010, -030, -040, and -050 all have the same emission factor, while the charge rate for process 305006010 equals the sum of the charge rates for processes -030, -040, and -050. Similar remarks apply to MSCC 305007010, -030, -040, and -050. Computations have been performed during this study for each of these -030, -040, and -050 categories by fuel type (current and projected to 1982) and are available on request. They are not listed in the printouts of Section 9.2, however, as they provide no additional information on total particulates generated (all of which are accounted for in the -010 category). Moreover, their inclusion in the computer data base, in accordance with existing NEDS format, would result in an erroneous double counting of emissions for kiln operations.

A new process subcategory was added to sand and gravel processing (MSCC 305025000) in that open storage was included as a source of PART emissions and is listed as MSCC 305025992. The value of 0.61 lb/ton, as determined for MSCC 305020070, was used. Neither NEDS nor AP-42 lists such a category for sand and gravel, but this study considered it appropriate to do so in view of the prevalence of open storage in sand and gravel operations. As noted, the revised AP-42 emission factor for open storage of crushed stone was based on measurements performed at a sand and gravel plant. This new process category is a major contributor to the indicated PART emissions from sand and gravel plants, as shown in Tables 9-2-a and 9-3-a.

Finally, it should be noted that the primary and secondary crushing operations of limestone attributed to lime production (MSCC 305016010 and -020) also represent a portion of the charge rate for the corresponding MSCC 305020010 and -020 categories for stone quarrying/processing. It was considered more appropriate to include these emissions in the inventory of lime production. The charge rates for processes MSCC 305020010 and -020 have therefore been decreased by the tonnage of limestone which is crushed for the purpose of lime production. The uncontrolled emission factors used for lime production represent revised values released by EPA in Supplement 7 of AP-42 (April 1977).

9.5 REFERENCES

9-1. Compilation of Air Pollutant Emission Factors, AP-42 2nd ed. (and supplements), U. S. Environmental Protection Agency, Research Triangle Park, North Carolina (April 1973).

9-2. T. G. Hopper, et al, Impact of New Source Performance Standards on 1985 National Emissions from Stationary Sources, U. S. Environmental Protection Agency, Office of Air Quality Planning and Standards, Research Triangle Park, North Carolina (October 1975); prepared by The Research Corporation of New England, Wethersfield, Connecticut.

9-3. Air Pollution Engineering Manual, 2nd Edition, AP-40, U. S. Environmental Protection Agency, Research Triangle Park, North Carolina (May 1973); prepared by Air Pollution Control District, County of Los Angeles.

9-4. Nationwide Emissions Summary, National Emissions Data System, U. S. Environmental Protection Agency, Research Triangle Park, North Carolina (November 15, 1976).

9-5. Air Pollution Emission Factors, PB-206 924, TRW Systems Group, National Air Pollution Control Administration, Washington, D. C. (April 1970).

9-6. Source Inventory and Emission Factor Analysis, NTIS PB-247743, PEDCO-Environmental Specialists, Inc. (September 1974).

9-7. C. Cowhered, et al., Development of Emission Factors for Fugitive Dust Sources, NTIS PB-238 262, U. S. Environmental Protection Agency, Research Triangle Park, North Carolina (June 1974); prepared by Midwest Research Institute, Kansas City, Missouri.

SECTION X

WOOD PRODUCTS

10.1 INTRODUCTION

This section presents the results of the inventory of emissions from wood processing operations involved in the conversion of raw wood to various intermediate or finished products. The major processes of the wood industry are those involved in the manufacture of pulp, paper, plywood, and pulpboard. Wood waste energy conversion processes are normally classified under the "External Combustion in Boilers" category. However, emissions from this source were so small, compared to other boiler sub-categories, that they are not included anywhere in this report.

A National Emissions Data System (NEDS) computer tape and other sources of data on production histories and emission rates were used to select the specific processes and air pollutants which are significant compared to the emissions of these air pollutants from other stationary point sources. Table 10-1 shows those processes selected for further study. These categories are generally as described in Ref. 10-1, with the NEDS Source Classification Codes (SCCs) modified slightly (MSCCs) to allow for a more detailed breakdown of some of the categories (see Section 1.4.3 for further discussion of the MSCC coding system).

10.2 SUMMARY

The charge rates and emissions of each of the categories listed in Table 10-1 are presented in Tables 10-2-a and 10-3-a, and the corresponding uncertainties of each of these parameters in Tables 10-2-b and 10-3-b.

(Continued on page 10-11)

Table 10-1. Definition of Wood Products Processes

MSCC	Source Category	Charge Rate Unit
307001000	Kraft (sulfate) Pulping	Air dry tons unbleached
307001030	Multiple effects	Air dry tons unbleached
307001040	Recovery boiler/direct contact evaporator	Air dry tons unbleached
307001050	Smelt dissolving tank	Air dry tons unbleached
307001060	Lime kilns	Air dry tons unbleached
307001090	Liquor oxidation tower	Air dry tons unbleached
307001990	Other (not classified)	N. A.
307002000	Sulfite Pulping	Air dry tons unbleached
307002010	Liquor recovery	Air dry tons unbleached
307002040	Smelt tank	Air dry tons unbleached
307002990	Other (not classified)	N. A.
307004000	Paperboard - General	Tons of finished product
307004020	Fiberboard	Tons of finished product
307004990	Other (not classified)	N. A.
307006000	Tall Oil/Rosin	Tons of product
307006010	General	Tons of product
307007000	Plywood/Particleboard	Tons of product
307007010	Veneer drying	Tons of product
307007020	Sanding	Tons of product
307007990	Other (not classified)	N. A.
307008000	Sawmill Operations	Tons processed
307008990	Other (not classified)	N. A.
307020000	Furniture Manufacturing	Tons processed
307020990	Other (not classified)	N. A.
307999990	Other (not classified)	N. A.

Table 10-2-a. 1977 WOOD PRODUCTS EMISSIONS AND CHARGE RATES

INDUSTRIAL PROCESS, WOOD PRODUCTS PAGE 1

ANNUAL CHARGE RATES AND EMISSIONS PROJECTED TO 1977 RUN DATE= NOV 16,1977

MODIFIED SCC	TACRP (SCC UNITS)	EMISSIONS (MILLIONS OF TONS / YEAR) NOX	HC	CO	PART
307001000		.005	.005	.637	.273
307001030	37965000.	0.000	NEG	.001	0.000
307001040	37965000.	.003	.005	.513	.198
307001050	37965000.	NEG	NEG	.024	.047
307001060	37965000.	.002	0.000	.100	.025
307001090	37965000.	NEG	0.000	NEG	NEG
307001990	37965000.	NEG	NEG	NEG	.003
307002000		.000	NEG	.025	.007
307002010	1651100.	0.000	0.000	.025	.007
307002040	536370.	0.000	NEG	0.000	.000
307002990	1834400.	.000	NEG	NEG	.000
307004000	11132000.	NEG	.009	NEG	.001
307004020	7135000.	NEG	.005	0.000	.000
307004990	3997000.	NEG	.004	NEG	.000
307006000	447000.	NEG	.001	NEG	NEG
307006010	447000.	NEG	.001	NEG	NEG
307007000	62520000.	.003	.006	.001	.022
307007010	10520000.	.002	.004	0.000	.001
307007020	13900000.	0.000	0.000	0.000	.000
307007990	38100000.	.002	.002	.001	.021
307008000	161900000.	NEG	.001	.001	.021
307008990	161900000.	NEG	.001	.001	.021
307020000	2525000.	NEG	.004	NEG	.007
307020990	2525000.	NEG	.004	NEG	.007

Table 10-2-a. 1977 WOOD PRODUCTS EMISSIONS AND CHARGE RATES (Continued)

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                        INDUSTRIAL PROCESS, WOOD PRODUCTS                          PAGE  2
ANNUAL CHARGE RATES AND EMISSIONS PROJECTED TO 1977     RUN DATE= NOV 16,1977
 MODIFIED          TACRF                 EMISSIONS (MILLIONS OF TONS / YEAR)
   SCC          (SCC UNITS)         NOX            HC             CO            PART
307999000                0.         0.000          0.000          0.000          0.000
307999990                0.         0.000          0.000          0.000          0.000
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Table 10-2-b. 1977 WOOD PRODUCTS UNCERTAINTIES

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                         INDUSTRIAL PROCESS, WOOD PRODUCTS                             PAGE  1
          TACF AND EMISSION UNCERTAINTIES PROJECTED TO 1977       RUN DATE= NOV 16,1977
 MODIFIED          TACRF                   EMISSIONS (MILLIONS OF TONS / YEAR)
   SCC          (SCC UNITS)          NOX             HC              CO            PART
307001000
                                   +  .038       +  .001        +  .397        +  .172
                                   -  .003       -  .001        -  .397        -  .201

307001030    +      3500000.       + 0.000          NEG         +  .001        + 0.000
             -      3500000.       - 0.000          NEG         -  .001        - 0.000
307001040    +      3500000.       +  .038       +  .001        +  .384        +  .167
             -      3500000.       -  .003       -  .001        -  .384        -  .198
307001050    +      3500000.          NEG           NEG         +  .007        +  .039
             -      3500000.          NEG           NEG         -  .007        -  .039
307001060    +      3500000.       +  .000       + 0.000        +  .100        +  .002
             -      3500000.       -  .000       - 0.000        -  .100        -  .002
307001090    +      3500000.          NEG        + 0.000           NEG            NEG
             -      3500000.          NEG        - 0.000           NEG            NEG
307001990    +      3500000.          NEG           NEG            NEG         +  .000
             -      3500000.          NEG           NEG            NEG         -  .000

307002000
                                   +  .000          NEG         +  .002        +  .001
                                   -  .000          NEG         -  .002        -  .001

307002010    +       143610.       + 0.000       + 0.000        +  .002        +  .001
             -       143610.       - 0.000       - 0.000        -  .002        -  .001
307002040    +        63031.       + 0.000          NEG         + 0.000        +  .000
             -        63031.       - 0.000          NEG         - 0.000        -  .000
307002990    +        74330.       +  .000          NEG            NEG         +  .000
             -        74330.       -  .000          NEG            NEG         -  .000

307004000    +       225620.          NEG        +  .000           NEG         +  .000
             -       225620.          NEG        -  .000           NEG         -  .000

307004020    +       198250.          NEG        +  .000        + 0.000        +  .000
             -       198250.          NEG        -  .000        - 0.000        -  .000
307004990    +       107700.          NEG        +  .000           NEG         +  .000
             -       107700.          NEG        -  .000           NEG         -  .000

307006000    +        50062.          NEG        +  .000           NEG            NEG
             -        50062.          NEG        -  .000           NEG            NEG
```

Table 10-2-b. 1977 WOOD PRODUCTS UNCERTAINTIES (Continued)

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                        INDUSTRIAL PROCESS, WOOD PRODUCTS                              PAGE  2
TACR AND EMISSION UNCERTAINTIES PROJECTED TO 1977         RUN DATE= NOV 16,1977
 MODIFIED          TACRF                   EMISSIONS (MILLIONS OF TONS / YEAR)
   SCC          (SCC UNITS)        NOX            HC             CO             PART

307006010   +     50062.           NEG      +  .000             NEG             NEG
            -     50062.           NEG      -  .000             NEG             NEG

307007000   +    218630.      +  .000       +  .000        +  .000        +  .003
            -    218630.      -  .000       -  .000        -  .000        -  .003

307007010   +    100000.      +  .000       +  .000        + 0.000        +  .000
            -    100000.      -  .000       -  .000        - 0.000        -  .000
307007020   +    101980.      + 0.000       + 0.000        + 0.000        +  .000
            -    101980.      - 0.000       - 0.000        - 0.000        -  .000
307007990   +    165930.      +  .000       +  .000        +  .000        +  .003
            -    165930.      -  .000       -  .000        -  .000        -  .003

307008000   +         0.           NEG      + 0.000        + 0.000        + 0.000
            -         0.           NEG      - 0.000        - 0.000        -  .017

307008990   +         0.           NEG      + 0.000        + 0.000        + 0.000
            -         0.           NEG      - 0.000        - 0.000        -  .017

307020000   +    200000.           NEG      +  .000             NEG       +  .001
            -    200000.           NEG      -  .000             NEG       -  .001

307020990   +    200000.           NEG      +  .000             NEG       +  .001
            -    200000.           NEG      -  .000             NEG       -  .001

307999000   +         0.      + 0.000       + 0.000        + 0.000        + 0.000
            -         0.      - 0.000       - 0.000        - 0.000        - 0.000

307999990   +         0.      + 0.000       + 0.000        + 0.000        + 0.000
            -         0.      - 0.000       - 0.000        - 0.000        - 0.000
```

Table 10-3-a. 1982 WOOD PRODUCTS EMISSIONS AND CHARGE RATES

INDUSTRIAL PROCESS, WOOD PRODUCTS PAGE 1

ANNUAL CHARGE RATES AND EMISSIONS PROJECTED TO 1982 RUN DATE= NOV 16,1977

MODIFIED SCC	TACRF (SCC UNITS)	EMISSIONS (MILLIONS OF TONS / YEAR) NOX	HC	CO	PART
307001000		NEG	NEG	.375	.285
307001030	44130000.	0.000	NEG	0.000	0.000
307001040	44130000.	0.000	0.000	.265	.197
307001050	44130000.	NEG	NEG	0.000	.055
307001060	44130000.	0.000	0.000	.110	.030
307001030	44130000.	NEG	0.000	NEG	NEG
307001990	44130000.	NEG	NEG	NEG	.004
307002000		.000	NEG	.021	.006
307002010	1374100.	0.000	0.000	.021	.006
307002040	441570.	0.000	NEG	0.000	.000
307002990	1495700.	.000	NEG	NEG	.000
307004000	13297000.	NEG	.007	NEG	.001
307004020	8800000.	NEG	.004	0.000	.001
307004990	4497000.	NEG	.003	NEG	.000
307006000	392000.	NEG	.001	NEG	NEG
307006010	392000.	NEG	.001	NEG	NEG
307007000	70520000.	.002	.004	.001	.023
307007010	12520000.	.002	.003	0.000	.001
307007020	16400000.	0.000	0.000	0.000	.000
307007990	41600000.	0.000	.000	.001	.022
307008000	162400000.	NEG	.001	.001	.021
307008990	162400000.	NEG	.001	.001	.021
307020000	2650000.	NEG	.004	NEG	.004
307020990	2650000.	NEG	.004	NEG	.004

Table 10-3-a. 1982 WOOD PRODUCTS EMISSIONS AND CHARGE RATES (Continued)

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                          INDUSTRIAL PROCESS, WOOD PRODUCTS                              PAGE  2
ANNUAL CHARGE RATES AND EMISSIONS PROJECTED TO 1982     RUN DATE= NOV 16,1977
 MODIFIED          TACRF                       EMISSIONS (MILLIONS OF TONS / YEAR)
   SCC          (SCC UNITS)           NOX               HC               CO               PART
307999000                 0.          0.000            0.000            0.000            0.000
307999990                 0.          0.000            0.000            0.000            0.000
```

Table 10-3-b. 1982 WOOD PRODUCTS UNCERTAINTIES

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                        INDUSTRIAL PROCESS, WOOD PRODUCTS                       PAGE  1
TACR AND EMISSION UNCERTAINTIES PROJECTED TO 1982        RUN DATE= NOV 16,1977
 MODIFIED         TACRF                   EMISSIONS (MILLIONS OF TONS / YEAR)
   SCC         (SCC UNITS)          NOX           HC            CO           PART
307001000                           NEG           NEG        +  .468      +  .170
                                    NEG           NEG        -  .287      -  .202

307001030   +     7000000.     + 0.000           NEG        + 0.000      + 0.000
            -     7000000.     - 0.000           NEG        - 0.000      - 0.000
307001040   +     7000000.     + 0.000       + 0.000        +  .452      +  .164
            -     7000000.     - 0.000       - 0.000        -  .265      -  .197
307001050   +     7000000.          NEG           NEG        + 0.000      +  .046
            -     7000000.          NEG           NEG        - 0.000      -  .046
307001060   +     7000000.     + 0.000       + 0.000        +  .123      +  .005
            -     7000000.     - 0.000       - 0.000        -  .110      -  .005
307001090   +     7000000.          NEG      + 0.000           NEG           NEG
            -     7000000.          NEG      - 0.000           NEG           NEG
307001990   +     7000000.          NEG           NEG           NEG      +  .001
            -     7000000.          NEG           NEG           NEG      -  .001

307002000                      +  .000           NEG        +  .005      +  .001
                               -  .000           NEG        -  .005      -  .001

307002010   +      348550.     + 0.000       + 0.000        +  .005      +  .001
            -      348550.     - 0.000       - 0.000        -  .005      -  .001
307002040   +      138010.     + 0.000           NEG        + 0.000      +  .000
            -      138010.     - 0.000           NEG        - 0.000      -  .000
307002990   +       86023.     +  .000           NEG           NEG      +  .000
            -       86023.     -  .000           NEG           NEG      -  .000

307004000   +      387260.          NEG      +  .000           NEG      +  .000
            -      387260.          NEG      -  .000           NEG      -  .000

307004020   +      363140.          NEG      +  .000        + 0.000      +  .000
            -      363140.          NEG      -  .000        - 0.000      -  .000
307004990   +      134540.          NEG      +  .000           NEG      +  .000
            -      134540.          NEG      -  .000           NEG      -  .000

307006000   +       50249.          NEG      +  .000           NEG           NEG
            -       50249.          NEG      -  .000           NEG           NEG
```

Table 10-3-b. 1982 WOOD PRODUCTS UNCERTAINTIES (Continued)

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                          INDUSTRIAL PROCESS, WOOD PRODUCTS                      PAGE  2
TACR AND EMISSION UNCERTAINTIES PROJECTED TO 1982         RUN DATE= NOV 16,1977
 MODIFIED          TACRF               EMISSIONS (MILLIONS OF TONS / YEAR)
   SCC          (SCC UNITS)          NOX           HC            CO            PART
307006010    +     50249.            NEG       +  .000          NEG            NEG
             -     50249.            NEG       -  .000          NEG            NEG

307007000    +    340480.        +  .000       +  .000       +  .000       +  .004
             -    340480.        -  .000       -  .000       -  .000       -  .004

307007010    +    136010.        +  .000       +  .000       + 0.000       +  .000
             -    136010.        -  .000       -  .000       - 0.000       -  .000
307007020    +    122070.        + 0.000       + 0.000       + 0.000       +  .000
             -    122070.        - 0.000       - 0.000       - 0.000       -  .000
307007990    +    287270.        + 0.000       +  .000       +  .000       +  .004
             -    287270.        - 0.000       -  .000       -  .000       -  .004

307008000    +         0.            NEG       + 0.000       + 0.000       + 0.000
             -         0.            NEG       - 0.000       - 0.000       -  .017

307008990    +         0.            NEG       + 0.000       + 0.000       + 0.000
             -         0.            NEG       - 0.000       - 0.000       -  .017

307020000    +    200000.            NEG       +  .000          NEG        +  .000
             -    200000.            NEG       -  .000          NEG        -  .000

307020990    +    200000.            NEG       +  .000          NEG        +  .000
             -    200000.            NEG       -  .000          NEG        -  .000

307999000    +         0.        + 0.000       + 0.000       + 0.000       + 0.000
             -         0.        - 0.000       - 0.000       - 0.000       - 0.000

307999990    +         0.        + 0.000       + 0.000       + 0.000       + 0.000
             -         0.        - 0.000       - 0.000       - 0.000       - 0.000
```

The most significant air pollution emissions in this category are particulates (PARTS), primarily from the Kraft pulping process. Total carbon monoxide (CO) emissions are also relatively high, but there are currently no required controls on these emissions. All CO emissions reported in NEDS are based on estimates rather than on measured values or on well-founded emission factors.

Total PART emissions from the entire wood products category are estimated to be 1.87 percent of those from all stationary point sources, with about 96 percent of these emissions resulting from the Kraft pulping process. Similarly, 2.11 percent of the CO emissions from all stationary point sources results from all sources defined within the wood products industry, with 82 percent of these from the Kraft pulping process. Although PART and CO emissions result from several subprocesses in the overall Kraft (sulfate) pulping process, the predominant source of these emissions is a combustion process in the recovery furnace. Here, the inorganic cooking chemicals, used to dissolve the lignin in the wood, are recovered essentially by burning off the organic content.

Emission controls for both PART and CO are being implemented in Kraft mills. Although a 16 percent increase in output from the Kraft mills is projected over the next five years, only a 4 percent rise in PART emissions and a 41 percent decrease in CO emissions are projected over the same period.

Although sulfur compounds are the most significant emissions from the wood products category of stationary sources, they are not within the defined scope of this inventory.

10.3 PROCESSES EVALUATED

A survey of the NEDS data base (Ref. 10-1) was conducted to determine which of the point sources contributed significantly to the inventory. The criteria of selection was based on the annual charge rate of significant emissions. The selected processes are discussed in the following paragraphs.

10.3.1 Pulp and Paper Manufacturing

The chemical pulping process, which frees the wood fibers by dissolving the binding material (lignin) in chemical solutions, was found to be the only portion of the pulp and paper manufacturing process that required detailed study (Ref. 10-2). Furthermore, only the Kraft (sulfate) process and the sulfite process were emphasized.

In June 1971, Kraft (sulfate) pulping accounted for 67 percent of all wood pulp produced (Ref. 10-3). By 1976, this production had grown to 72 percent. This process involves a chemical recovery cycle to reclaim the liquor. The spent sodium sulfite is converted to sodium sulfate, subsequently reduced to sodium sulfide, and concentrated by evaporation. PART and CO emissions primarily result from this liquor recovery cycle. The spent liquor passes through five serial phases in the recovery process, and each of these phases has the potential of producing some air pollutant emissions. Separate emission factors are listed for each of these phases, but all are based on the same process charge rate, the amount of pulp (air-dried, unbleached) produced by the plant.

The five phases in the chemical recovery cycle are as follows:

a. Multiple Effects Evaporation. The multiple effects evaporation phase concentrates the weak "black liquor" in order to facilitate combustion of the dissolved organic material.

b. Recovery Furnace System. This phase is used to recover the chemicals from the black liquor. The concentrated black liquor is sprayed into the lower part of the furnace, and essentially all of the recovered chemicals are removed from the bottom of the furnace as molten smelt, consisting principally of sodium sulfide and sodium carbonate.

c. Liquor Oxidation Towers. In this phase, the sulfide present in the black liquor is oxidized to thiosulfate, which does not react with the acidic gases in the recovery furnace flue gases. This prevents their stripping in the form of hydrogen sulfide.

d. Smelt Dissolving Tanks. The smelt dissolver is a large tank into which the molten sodium carbonate and sodium sulfide that accumulate on the floor of the recovery furnace are dissolved in water to form "green liquor." It is equipped with an agitator to assist dissolution and a steam or liquid shatterjet system to break up the smelt stream before it enters the solution.

e. Lime Kiln. The lime kiln is the final phase in the closed-loop recovery system. In this phase, the green liquor is converted to "white liquor" for reuse. The kiln supplies calcium oxide, which is wetted by the water in the green liquor solution to form calcium hydroxide.

PART emissions from the entire process occur primarily from the recovery furnace, the smelt dissolving tank, and the lime kiln. Major sources of CO emissions are the recovery furnace and lime kiln. The major cause of CO emissions is operation of the recovery furnace well above rated capacity. Under these conditions, it becomes impossible to maintain a sufficiently high air/organic-material ratio (oxidizing conditions).

PART control is provided on recovery furnaces in a variety of ways. In mills where either a cyclonic scrubber or cascade evaporator serves as the direct contact evaporator, further control is necessary because these devices are generally only 20 to 50 percent efficient in PART removal. Generally, an electrostatic precipitator (ESP) is employed after the direct contact evaporator to provide an overall PART control efficiency of 85 to better than 99 percent. In a few mills, however, a venturi scrubber is utilized as the direct contact evaporator, simultaneously providing 80 to 90 percent PART control. In either case, auxiliary scrubbers may be included after the precipitator or the venturi scrubber to provide additional control of PART.

PART control on lime kilns is generally accomplished by scrubbers. Smelt-dissolving tanks are commonly controlled by mesh pads but employ scrubbers when further control is needed.

Several new mills have incorporated recovery systems that eliminate the conventional direct contact evaporators. In one system, preheated combustion air, rather than flue gases, provides direct contact evaporation. In the other, the multiple-effect evaporator system is extended to include and replace the direct contact evaporator. In both of these systems, emissions of sulfur compounds from the recovery furnace and direct contact evaporator reportedly can be reduced by more than 95 percent from conventional uncontrolled systems (Ref. 10-4).

10.3.2 Sulfite Pulping

Sulfite pulp is generally made from soft wood. The principal products of pulp are high-grade book and bond papers and tissues. The pulp can also be combined with other pulp to produce cellophane, rayon, acetate, films, and related products. Sulfite pulp was once the major pulp used in all grades of paper other than paperboard, coarse paper, and newsprint. It has steadily been losing ground to bleached and semibleached Kraft pulp in these traditional end uses. Production has been steadily declining since 1966 (Ref. 10-2).

The emissions from the sulfite processing are again a result of the liquor recovery process. Sulfur compounds are the most important air pollution emission from this process, but sulfur emissions are not within the scope of this study. The only significant PART source in the sulfite pulping process is the absorption system handling the recovery furnace exhaust.

10.3.3 Other Processes

The other activities of the wood industry which contribute to the emissions inventory deal mainly with the sanding operations of the plywood, pulp board, and furniture industries.

10.4 DATA ANALYSIS

The production rates of the various categories within the wood industry were gathered from Survey of Current Business (Ref. 10-5) and the Marketing Guide to the Paper and Pulp Industry (Ref. 10-3). Production rates from these sources were consistent and consistent, also, with rates used in other studies, such as the Particulate Pollutant System Study (Ref. 10-6). In the paper processing categories, annual charge rates (air-dried, unbleached pulp production rates) derived from the NEDS data must be properly interpreted. The method of reporting the data may tend to generate production rates much higher than the actual rates. This is because the emissions and emission factors from and for the serial processes in the chemical recovery cycle are reported separately, as individual processes with different source classification codes (SCCs), despite the fact that all are related or keyed to the same pulp production rate. Further, it is the chemical treatment liquor, rather than the pulp, which is the primary fluid being treated by these processes. In plants where a single pulp production rate is supported by multiple chemical treatment liquor recovery systems or by multiple units of a given process operating in parallel (for example, multiple recovery furnaces), the assumed relations between pulp production rates, emission factors, and emissions may be grossly in error. In the emissions data shown in Tables 10-2 and 10-3, the pulp charge rates are shown and are identical for each of the recovery process categories (MSCCs), but they are not summed in any subsequent summary level. While the sums of the emissions in these summary levels are correct, the sums of the pulp production rates would be high by as much as 500 percent.

Emission factors for this category were, for the most part, taken from Particulate Pollutant System Study (Ref. 10-6) and Compilation of Air Pollutants Emission Factors, AP-42 (Ref. 10-4). Emission factors not available through these publications were generated from measured emissions and production rates recorded in the NEDS data base.

10.5 REFERENCES

10-1. NEDS Source Classification Codes and Emission Factor Listing (SCC Listing), Office of Air and Waste Material, Office of Air Quality Planning and Standards, U. S. Environmental Protection Agency, Washington, D.C. (July 1974).

10-2. Atmospheric Emissions from the Pulp and Paper Manufacturing Industry, EPA-450/1-73-002, U. S. Environmental Protection Agency, Office of Air Quality Planning and Standards, Research Triangle Park, North Carolina (September 1973).

10-3. Marketing Guide to the Paper and Pulp Industry (October 1973).

10-4. Compilation of Air Pollutant Emission Factors, AP-42 2nd ed. (and supplements), U. S. Environmental Protection Agency, Research Triangle Park, North Carolina (April 1973).

10-5. Survey of Current Business, U. S. Department of Commerce, Washington, D. C. (February 1976).

10-6. Particulate Pollutant System Study, Volume III, Handbook of Emissions Properties, PB-203 522, Midwest Research Institute, U. S. Environmental Protection Agency, Durham, North Carolina (May 1971).

APPENDIX A

CONVERSION FACTORS

To Convert From	To	Multiply By
Barrel (42 gallons)	Cubic meters	1.590×10^{-1}
British thermal unit	Joules	1.055×10^{3}
Fahrenheit (temperature)	Kelvin	$T_K = \frac{5}{9}(T_F + 459.67)$
Foot	Meters	3.048×10^{-1}[a]
Gallon (U.S. liquid)	Cubic meters	3.785×10^{-3}
Horsepower $\left(550 \frac{\text{ft-lbs}}{\text{sec}}\right)$	Watts	7.457×10^{2}
Inch	Meters	2.54×10^{-2}[a]
Lb_f (pound force)	Newtons	4.448
Lb_m (pound mass)	Kilograms	4.536×10^{-1}
Ton (short, 2000 pounds)	Kilograms	9.072×10^{-2}
Lb_m per gallon	Kilogram per cubic meters	1.198×10^{2}
Cubic feet	Cubic meter	2.832×10^{-2}
Lb_m per cubic foot	Kilograms per cubic meter	1.602×10^{1}
Btu per ton	Joules per kilogram	1.163
Btu per gallon	Joules per cubic meter	2.787×10^{5}
Btu per cubic foot	Joules per cubic meter	3.726×10^{4}

[a] Exact.

APPENDIX B

GLOSSARY

ACR	annual charge rate
API	American Petroleum Institute
bhp	brake horsepower
BTX	benzene, toluene, xylene
CO	carbon monoxide
EEI	Edison Electric Institute
EPA	Environmental Protection Agency
H_2	hydrogen
HC	hydrocarbons
IC	internal combustion
KPPH	thousands of pounds per hour
MMBtu/hr	millions of British thermal units per hour
MSCC	modified source classification code
N	nitrogen
NEC	not elsewhere classified
NEDS	National Emissions Data System
nm	nanometer (formerly millimicron)
NH_3	ammonia
NO_x	oxides of nitrogen

PART	particulate matter
PPM	parts per million
SCC	source classification code (NEDS)
SIC	standard industrial classification
SO_2	sulfur dioxide
TACRP	total annual charge rate projected
T_F	temperature, degree Fahrenheit
T_k	temperature, Kelvin